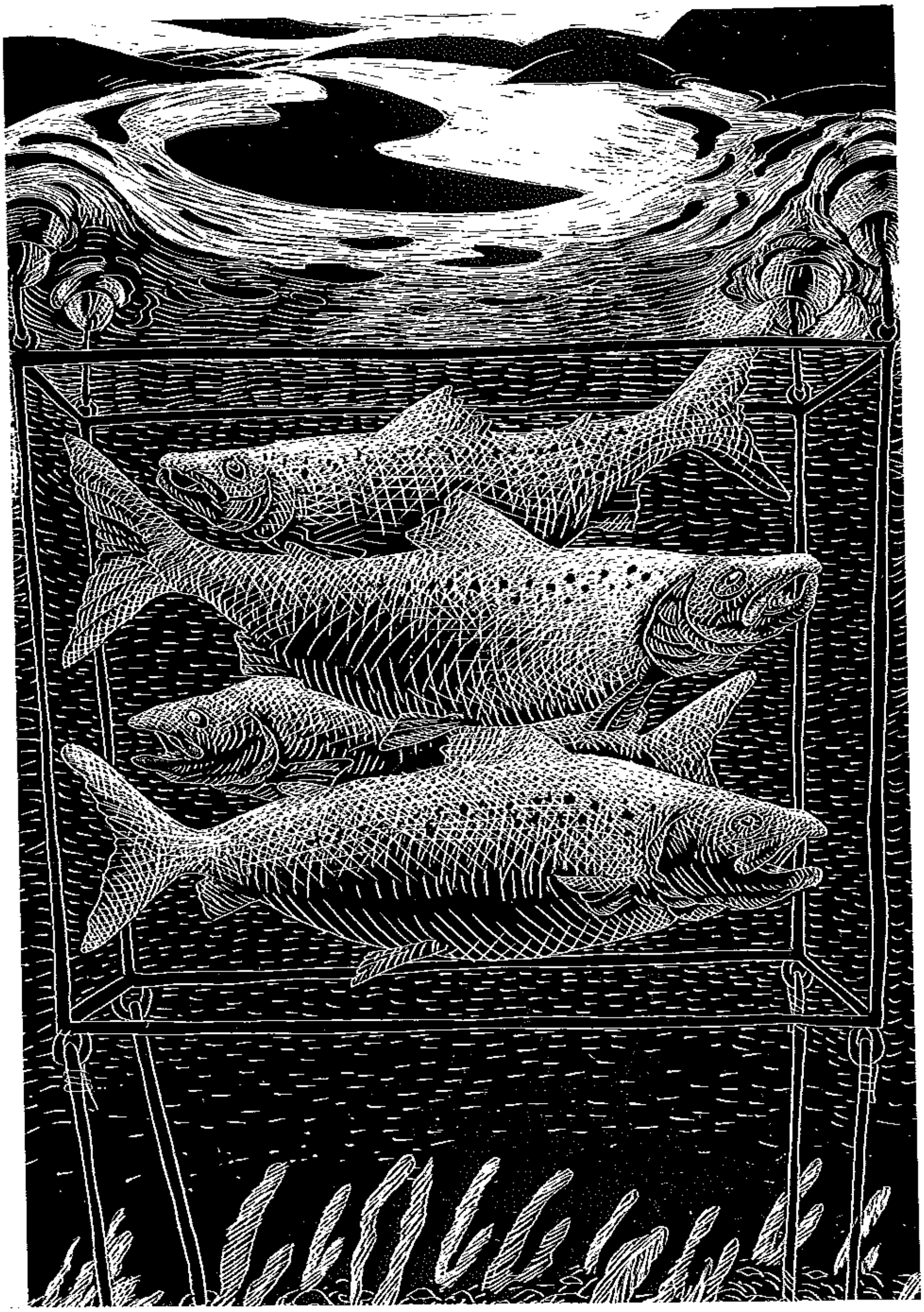
# Leaping in the dark

A REVIEW
of
THE ENVIRONMENTAL IMPACTS
of
MARINE SALMON FARMING
in
SCOTLAND
and
PROPOSALS FOR CHANGE



A report
for
Scottish Wildlife
and
Countryside Link
by
**Alison Ross**
June 1997

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– a review of the environmental impacts of marine salmon farming in Scotland and proposals for change

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## Leaping in the dark

– a review of the environmental impacts of marine salmon farming in Scotland and proposals for change

# EXECUTIVE SUMMARY

The purpose of this report is to review the environmental impact of marine salmon farming in Scotland and to suggest changes in policy and practice to improve the situation. Scottish Wildlife and Countryside Link commissioned the report to highlight clear deficiencies in the strategic planning and regulation of this industry and the need for application of the precautionary principle by government and industry alike. SWCL's motivation for producing the review is concern for the environment itself.

Two important developments have arisen that provide the opportunity for the fundamental reform of the regulatory framework in which the industry operates. First, the Scottish Office is currently reviewing the controversial role of the Crown Estate in granting and regulating fish farm leases. Second, the Scottish Environment Protection Agency (SEPA) has been established with the remit to provide an integrated environmental protection system for Scotland that will contribute towards sustainable development. SEPA's duties also include the conservation of aquatic flora and fauna.

A first draft of this document was discussed with representatives of the salmon farming industry, the Scottish Office, SEPA, the planning authorities and Scottish Natural Heritage (SNH). This final report has benefited from their comments. It is intended that all interested parties will find the report a constructive input to the debate.

The report highlights the following key areas for improvement:

- the need for national strategic guidance,
- the need for democratic and environmentally sensitive planning control,
- the need for effective regulation and monitoring of the industry's operations.

With the production of an estimated 83,000 tonnes of salmon in 1996, predicted to rise to 132,000 tonnes by the year 2000, the need for strategic guidance on the development of the industry is just as great if not greater than ever before. However, the Government has no statement of policy on marine fish farming that addresses its social, economic and environmental objectives.

**The Scottish Office must produce clear strategic guidance on the development of the industry as a matter of urgency.**

Much of the current growth is occurring through the expansion of farm sites, with over 50 sites now producing more than 1000 tonnes and proposals being made for sites of over 2000 tonnes. Clearly, this trend has implications for the direct environmental impact of sites and also for fish health, and therefore the use of chemotherapeutants. This trend also makes the role of planning control and proper environmental assessment all the more crucial. However, the Crown Estate has continued to perform these functions in a totally unsatisfactory fashion, without transparency or accountability in its decision-making and without adequate consideration of the ecological impact of individual sites, let alone their cumulative effects. The process of environmental assessment has been almost totally avoided.

**In order to achieve a more democratic process that takes proper account of ecological constraints and the needs of sustainable development, we recommend that the powers of local planning authorities be extended to include responsibility for planning decisions on the siting of marine fish farms.**

**We recommend that SEPA be identified as the Competent Authority for Environmental Assessment, working in close consultation with the planning authorities and SNH.**

Regulation of the operations of the industry has been inadequate and fragmented between various regulatory bodies. Examination of the specific cases of medicine and chemical use, interactions with predatory wildlife and the impact on wild salmonid stocks reveal major problems both in terms of current practices and future developments. Some areas of impact, most notably acoustic disturbance from predator deterrent devices and the ecological and genetic impact of escaped salmon on wild stocks, appear to have no clear regulatory structure or responsible body.

**We recommend that SEPA be charged with the role of regulating the operations of the industry, insofar as they are relevant to its environmental impact. This role should include:**

- **conducting or co-ordinating, as appropriate, functions relating to the control of waste, medicine and chemical discharges, and impacts on wild fish and other wildlife:**
- **powers to set and enforce standards relating to fish health, husbandry and site management in consultation with other relevant bodies such as SOAEFD and SNH;**
- **the establishment of a unified monitoring body with a vessel based capacity to monitor and police the operations of the industry.**

We recognise this package of proposals is just one of several possible options, but one we consider can provide for proper environmental protection and development of the industry on a more accountable, consistent and sustainable basis. SWCL presents this for consideration in discussions we trust will ensue in the near future as the Scottish Office, industry and regulatory and other interested bodies together seek the best arrangements to ensure the environment is protected.

# 1 INTRODUCTION

1.1 In its first report on the Scottish salmon farming industry, Scottish Wildlife and Countryside Link assessed the state of the industry and its impact on the marine environment, making recommendations relating to policy, planning, regulation and practice (SWCL 1988). In a subsequent review (SWCL 1990), this assessment and its recommendations were revisited, finding the critique of the industry and its regulation were still valid and the recommendations for change even more urgent.

1.2 Now, almost a decade since its first report, this review provides an update on the status of the Scottish salmon farming industry and its environmental implications. The review was initiated because of significant developments occurring in the Scottish salmon farming industry that once again raise alarm about the clear deficiencies in the regulation and monitoring of the industry and the impact it is having on the environment. These developments include:

- rapid growth in the scale of the industry, in terms of the size of sites, tonnages produced and intensity of production;
- rapid developments in medicine and chemical treatments used by the industry, particularly in the context of sea lice control;
- use of new and highly intrusive sonic devices for scaring predatory wildlife from salmon farms; and
- a growing realisation of the potential impacts of salmon farming on wild salmon and trout populations.

1.3 In addition, various changes are occurring with respect to the regulatory framework in which salmon farming operates that raise important opportunties to address some of these issues. Most importantly, the Scottish Environment Protection Agency (SEPA) was established as the unified environment protection body for Scotland in April 1996. Also the role of development control of fish farming, which has been conducted by the Crown Estate since the industry's inception, is currently under review by the Scottish Office.

1.4 This paper is not intended to be a comprehensive analysis of the industry, but rather a broad assessment of changes that have taken place and current developments that are relevant to its impact. In particular, several issues have been identified that merit close attention either because of their acute environmental importance or because their significance has only recently emerged. Specifically, the use of chemical treatments, interactions with predatory wildlife and threats to wild salmonid stocks are examined in detail.

1.5 SWCL's motivation for producing this review is concern for the environment itself. We recognise the benefits the salmon farming industry has brought to many, often remote, coastal communities in terms of employment and economic revitalisation. However, these benefits can be sustained only if the industry operates in a way that protects the long term health of the environment on which it depends. Equally, these benefits must be weighed against any costs that accrue to other interests and to Scotland's natural heritage if the industry operates without due care for the environment.

1.6 As always, direct evidence of damage to the marine environment is extremely difficult to obtain, reflecting the problematic nature of effective monitoring and also the still limited understanding of this environment. However, the scarcity of data combined with inadequate regulation, the remoteness of operations and anecdotal evidence of continued low standards of practice give rise to a great cause for concern. Therefore, the approach taken in this review is based on the precautionary principle. Even in the absence of clear evidence of impacts, or indeed the lack of them, the precautionary principle is now widely accepted as the best approach to assessing and setting operational standards in order to prevent environmental damage.

1.7 This review addresses some aspects of the sustainability of the salmon farming industry, in terms of the way in which it operates and is regulated. However, the report does not address the question of whether salmon farming is itself a sustainable way of producing food fish in terms of global resource use. This is in doubt given the industry's total dependence on the largely unregulated exploitation of wild caught fish for feed. This broader perspective is extremely important and should be dealt with by a full environmental audit of the industry, in the contexts of total energy and resource inputs and of global fisheries management.

1.8 The current document takes account of consultations held with representatives of the salmon farming industry, the Scottish Office, the Scottish Environment Protection Agency (SEPA), the planning authorities and Scottish Natural Heritage (SNH). It is presented now as a discussion paper, to promote further debate of the issues raised and to hasten the introduction of appropriate regulatory and operational changes.

# PART I

## CURRENT STATUS OF MARINE SALMON FARMING

### Summary

The Scottish salmon farming industry, which grew extremely rapidly in the 1980s but, plateaued off in the early 1990s, has resumed its pattern of growth. Production, estimated at 83,300 tonnes in 1996, is predicted to rise to 132,000 tonnes by the year 2000. Earlier problems associated with poor fish survival and low prices, reduced the profitability of the industry and also changed its structure. Many small farms have gone out of business and production is increasingly concentrated in the hands of a few large companies. There has also been an increasing proportion of foreign ownership of the Scottish industry.

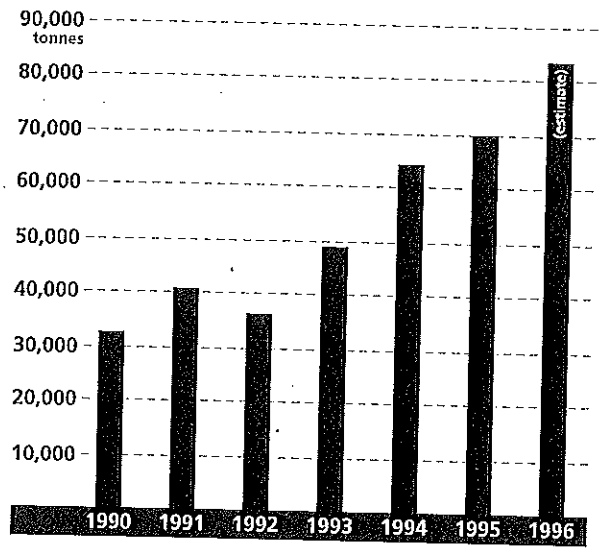
Correspondingly, production sites are also becoming larger, with some now proposed that would produce over 2000 tonnes of salmon. The increasing scale of farm sites has resulted in a higher productivity of fish per person, which means employment in the industry has not increased in line with production. The growing number of fish stocked per site has also raised concern that the risk of serious disease problems may be reintroduced.

## 2 SALMON PRODUCTION

2.1 In 1990 it was predicted that salmon production in Scotland, which had gone through a period of very rapid growth during the 1980s, would plateau off at around 40,000 tonnes in the early 1990s (DAFS 1990). This predicted cessation of growth was attributed to overproduction on a world scale and reduced profitability.

2.2 In reality, the period from 1990 saw a continued increase in production up to 1991 (40,593 tonnes) followed by a drop in production in 1992 (to 36,101 tonnes) (see figure 1). This slowing and fall in production was attributed to very poor survival rates in salmon (57.9% for the 1989 year class) due to a combination of the bacterial disease furunculosis and sea lice infestations. In 1993, a continued plateau in production was projected as a result of loss of confidence in the market for salmon and fears about the inability to control disease (SOAFD 1993).

**Figure 1. Annual Scottish farmed salmon production 1990-1996 (tonnes)**



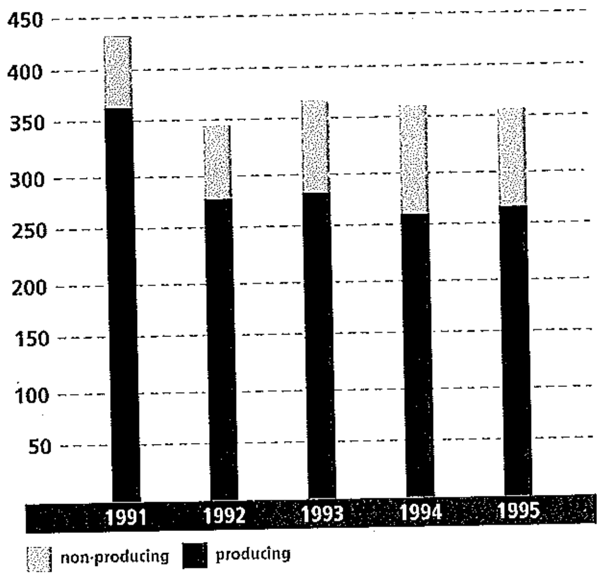

*source: SOAEFD*

2.3 Production then increased again at an accelerating rate, reaching 64,066 tonnes in 1994. A further increase to 70,060 tonnes was reported for 1995. This growth in production was linked to a substantial rise in survival rates, with 79% of fish recovered (harvested) from the 1992 year class, and increasing weight of fish. The increases were attributed to much more effective control of disease by both management techniques and use of vaccines. No major disease events or losses due to escape were reported in 1994. The 1995 production figures were attributed in part to advantageous growth conditions but also to the industry's ability to produce more and larger fish in successive years (SOAEFD 1995 & 1996).

2.4 In 1993, the oil spilt from the tanker MV Braer, which grounded on the south-western tip of Shetland, caused a serious loss of farmed salmon. Twenty salmon sea sites were affected, resulting in 3,549 tonnes of fish being slaughtered in 1993, and a further 1,852 tonnes in 1994.

2.5 It is worth noting the increase in production in 1994 was achieved with much the same cage capacity and smolt input as in 1993 and 1992, with productivity of fish per cage space increasing by 78% over this time. The number of marine sites in operation in 1995 was 268, with 91 sites listed as "non-producing" or fallow for the whole year (SOAEFD 1996). This was a slight increase on the 1994 figure but down on the number of sites in operation 1993 and 1992 (SOAFD 1995) (see figure 2).

Figure 2. Number of marine salmon sites 1991-1995




*source: SOAEFD*

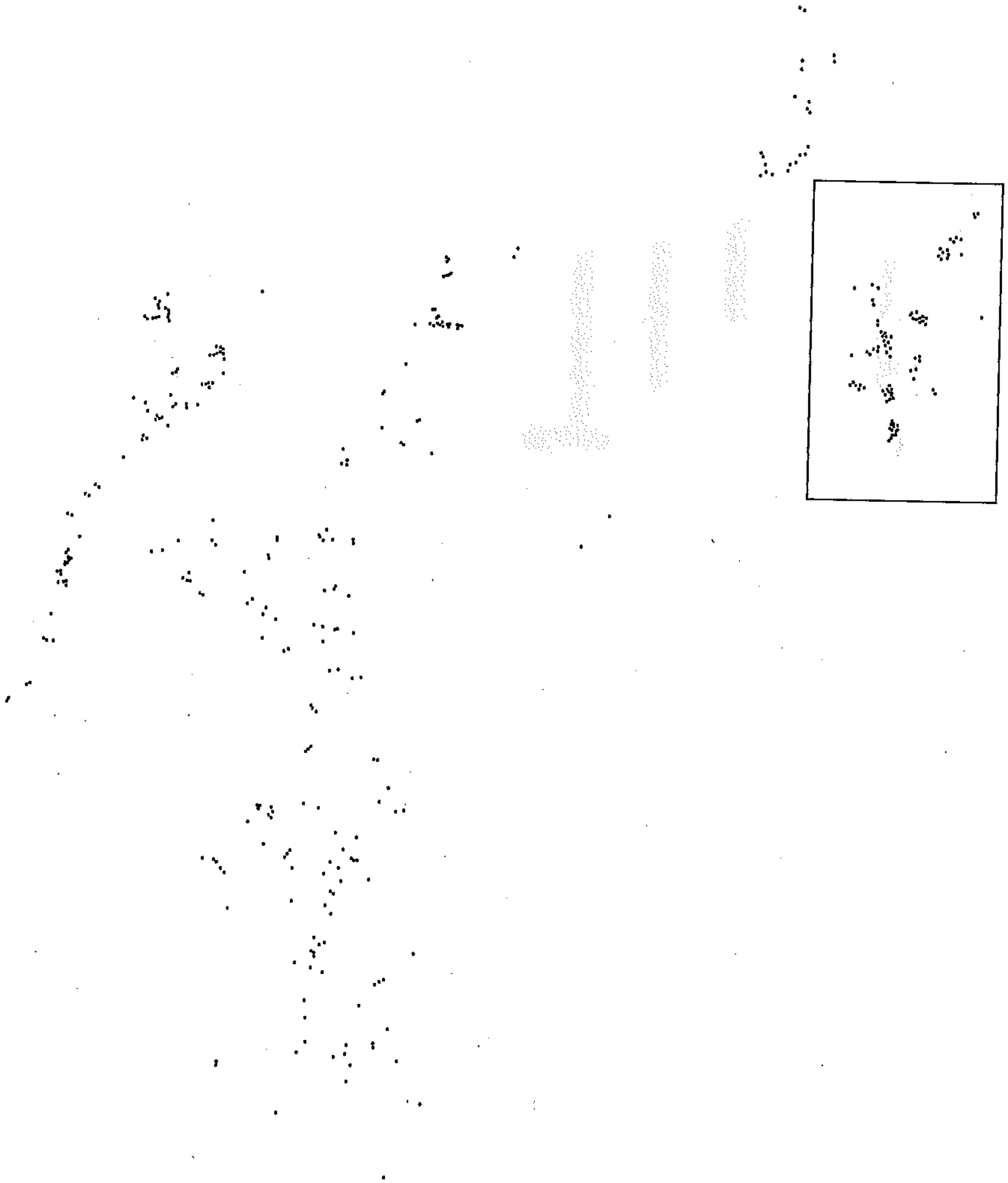
2.6 In 1995 SOAFD Marine Laboratory warned that "care needs to be exercised to ensure that optimal stocking levels are not exceeded and possible disease problems reintroduced" (SOAFD 1995).

2.7 SOAEFD estimated the annual production for 1996 was around 83,300 tonnes (SOAEFD 1996). This is in the context of total world production in 1995 of approximately 425,000 tonnes. The largest single salmon producing country, Norway produced 247,000 tonnes, with an additional 50,000 tonnes carried over ie. salmon that was not harvested due to market conditions. Chile produced roughly 100,000 tonnes including both Atlantic and Coho salmon (Scottish Salmon Growers Association pers.comm).

2.8 Based on the growth rate shown over the past four years, SEPA has calculated the expected Scottish salmon production to be about 132,000 tonnes in the year 2000. This compares with the SSGA's long term production projection of 140,000 tonnes (SEPA 1997).

2.9 Full data on the size and location of Scottish marine salmon farm sites are held by the Crown Estate Commission (CEC) as the owners of the sea bed around the UK and the body responsible for granting sea bed leases for salmon farms. Likewise, CEC holds all details of the duration and operational conditions that apply to the seabed leases that are issued. However, not all this information is accessible to interested parties which is a point of contention (see section 5). The location of all salmon farm sites under lease from the Crown Estate in 1996 is shown in figure 3.

Figure 3. Location of salmon farm sites under lease from the Crown Estate in 1996

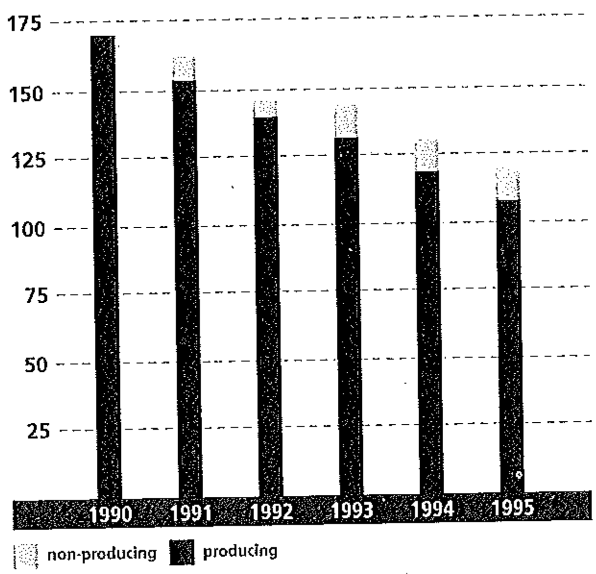


*source: the Crown Estate*

# 3 STRUCTURE OF THE INDUSTRY

3.1 The years since 1990 have seen a steady decline in the number of companies producing salmon (see figure 4). Not surprisingly, given the severe operational and financial difficulties faced by the industry during the early 1990s, this decline has affected small companies most profoundly, with many of the smaller operators having to go out of business or be taken over by larger companies.

**Figure 4. Number of salmon farming companies 1990-1995**



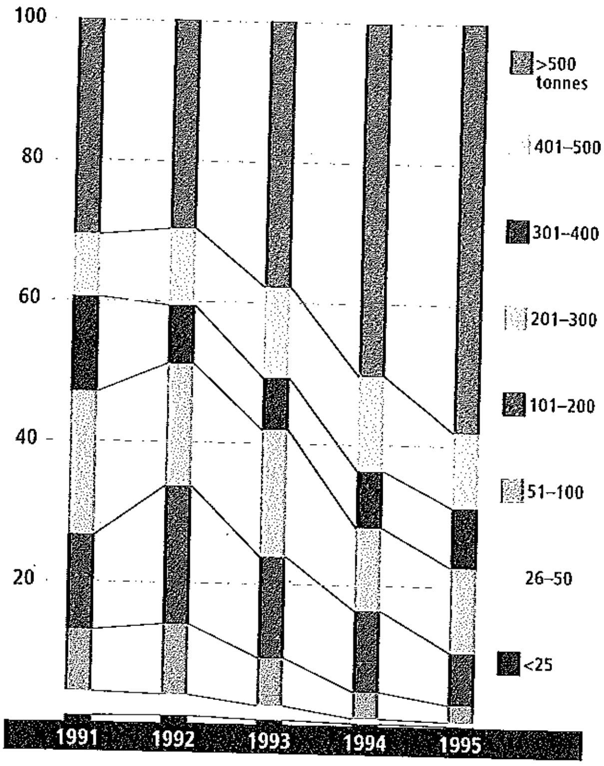

*source: SOAEFD*

3.2 There have also been buy-outs amongst the larger companies. Marine Harvest, previously the largest producer of Scottish farmed salmon, was bought in 1994 by Booker, whose McConnell Salmon was previously the second largest producer. The combined businesses, trading as Marine Harvest McConnell, formed the largest salmon farmer in the world, including production in Chile (Booker Annual Report and Financial Statements 1994).

3.3 There also appears to be an increasing interest in foreign ownership of Scottish salmon farms. The Norwegian company Norsk Hydro, which owns Golden Sea Produce has been actively acquiring site leases and is estimated to produce some 17% of Scottish farmed salmon (SSGA pers.comm). Indeed Norwegian companies are now reported to own over 50% of the salmon production in Shetland and around 30% of production in mainland Scotland (West Highland Free Press 21.2.97). A German company has recently bought a substantial portion of Shetland's production, exporting the salmon to Germany where it is smoked for retail. An increasing sector of the Western Isles production is in the hands of a Belgian company (SSGA pers.comm).

3.4 The shift from smaller to larger companies has also been reflected in a marked trend towards larger production sites, both in number and in share of overall production. Whereas in 1991, less than a third of production was accounted for by sites producing more than 500 tonnes, by 1994 more than half the salmon was produced at these largest sites (see figure 5). In 1995 this trend of increasing scale of production and company size continued. Of the 70,060 tonnes of salmon produced by 120 companies, 78% was produced by companies producing more than 500 tonnes each. Seven companies produced more than 2000 tonnes, accounting for 55% of the total production (SOAEFD 1996). More than 50 sites now produce over 1000 tonnes and applications are being made for production of over 2000 tonnes at individual sites (SEPA 1997).

Figure 5. Percentage of Scottish salmon production by size of sites (tonnes) 1991-1995

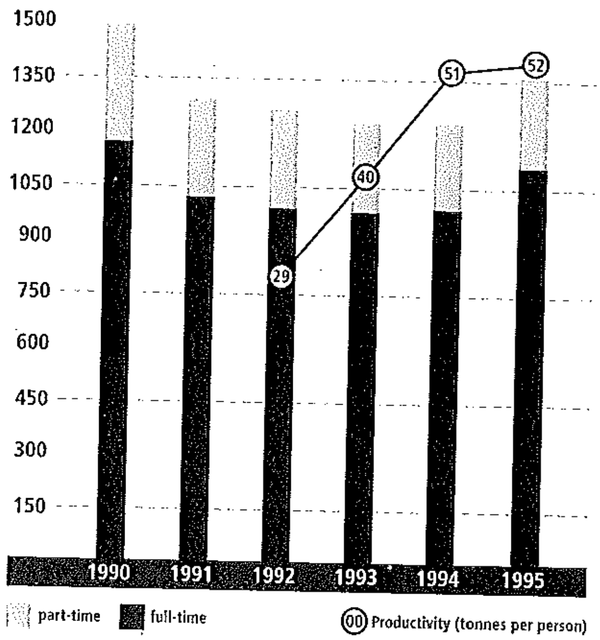



*source: SOAEFD*

3.5 Correspondingly, although there was substantial growth in employment during the 1980s, the years since 1990 saw a gradual decline in the number of people employed directly in the industry. The greatest proportion of jobs lost has been in the part-time sector, where there was a decline of some 25% between 1990 and 1994. This downward trend in employment was reversed in 1995 with an increase in jobs, most markedly in the full-time sector. Related to the growing scale of production, and probably more directly to the improved survival rate of the salmon to harvest in recent years, there has been a massive increase in the productivity of salmon per person employed (see figure 6).

3.6 Thus the further massive growth in production during the 1990s has not been accompanied by a corresponding increase in employment in the industry. Given also the increase in foreign ownership of the Scottish industry, the question arises as to whether the economic benefits associated with salmon farming are being out-grown by the potential costs to other sectors and to the environment, which are more directly related to the size of the industry.

Figure 6. Number of staff employed directly in salmon production (1990-1995) and productivity per person (tonnes)




*source: SOAEFD*

3.7 Growth in production continued in all regions up to 1994, with the highest production and employment recorded in Highland region. However, in 1995 both Highland region and Orkney saw a drop in production, although Highland maintained its leading position. In 1995 Strathclyde overtook Shetland for the position of second highest producer. The Western Isles saw the greatest increase in production between 1994 and 1995. The Western Isles also achieved the highest level of productivity per person in 1995, taking over this position from Strathclyde which, along with Highland and Orkney, experienced a decrease in productivity in 1995. Strathclyde maintained its position as producer of the heaviest salmon, although the mean weight was lower than in 1994 (SOAFD 1996).

## Other species

3.8 Halibut are now being produced at three commercial hatcheries, in addition to the Sea Fish Industry Authority (SFIA) facility at Ardtoe, each producing several thousand young fish per year. It is not clear where these fish will be grown-on although the hatcheries are linked to Marine Harvest McConnell, Murray Seafoods, Otterferry Salmon and Golden Sea Produce (P.Smith SFIA pers.comm.).

3.9 SFIA is currently looking for funding (largely from MAFF) for a cod farming project. While it is thought to be feasible to rear cod in captivity it is considered unlikely to be economical. However, given the current state of wild populations, rearing for restocking may be looked into (P.Smith pers.comm). An application has now been made for a sea bed lease to site a cod farm in Wester Ross. The applicant, a local fisherman, has already been catching young cod in the wild and rearing them in onshore tanks and now proposes to grow the fish on to maturity in sea cages.

# PART II

## STRATEGIC PLANNING AND REGULATION


### Summary

The marine salmon farming industry has continued to operate and grow in the absence of any strategic guidance or framework for its development, without a democratic and transparent system of planning control and with no effective process of environmental assessment and regulation of its impacts. Despite the strenuous criticism of this situation from many quarters over the past decade, the Scottish Office has resisted making the fundamental reforms that are needed to remedy these problems.

However, in 1996, the Scottish Office announced a review of the arrangements for assessing, granting and regulating marine fish farm leases that is expected to result in the Crown Estate being relieved of this role. This opens the door for the introduction of a system of more strategic and democratic planning for the industry and more effective assessment of the environmental implications of developments.

Also in 1996, the Scottish Environmental Protection Agency was established with the remit of providing an integrated environmental protection system for Scotland that will contribute towards sustainable development. This new unified body provides the opportunity for the introduction of more comprehensive regulation of the operation of the industry, in order to minimise its environmental impact; conducting or co-ordinating, as appropriate, functions relating to the control of pollution and impacts on wild fish and other wildlife.

SWCL welcomes these opportunities and proposes that:

- The Government produces clear strategic guidance for the development of the industry as a matter of urgency;
- The powers of local planning authorities be extended to include responsibility for planning decisions on the siting of marine fish farms;
- SEPA be charged with the role of regulating the operations of the industry, insofar as they are relevant to its environmental impact.

this recent increase is associated with companies acquiring new sites for rotation or fallowing but many are for expansion purposes or for the modification or growth of existing sites. Despite the major changes that have occurred in the industry, CEC has produced no policy guidelines on salmon farming development control since its guidelines on siting and its development strategy and area guidelines (1989). Even these were poorly conceived and have been half-heartedly implemented.

5.4 Numerous other criticisms have been levelled at the Crown Estate over its planning and regulation of fish farming. These include its lack of accountability over decisions, its failure to take account of ecological considerations, and obstructiveness over the provision of information. The view was expressed by one official consultee that CEC staff still seem to disbelieve fish farming has any impact on the environment.

5.5 An example of particularly bad practice is the Crown Estate's lax treatment of applications for salmon farms to take over shellfish farm sites. These cases are classified as lease modifications rather than new leases. Thus the applicants are required to provide even less information than for normal applications; amounting only to a map and a few words. Consultees are given even less time to evaluate the proposal – just 21 days. A recent example in 1996 involved an application by Marine Harvest McConnell to convert a shellfish site (six lines of 200 m) to a salmon farm of 30 large cages in Loch Sunart. The total area of the proposed cages was 7680 sq.m, which exceeds CEC's own threshold for an Environmental Assessment in this area (see section 6). However, CEC dealt with this application as a modification, with no details provided beyond the surface area of the cages and just 100 words of explanation. The procedure adopted over this case was challenged by SNH, Highland Council and the Scottish Office.

5.6 In its paper, *Scotland's Coasts – a Discussion Paper*, published in March 1996 (SOAEFD 1996), the Scottish Office states that, in the light of the changing requirements of the fish farming industry, "the Secretary of State and the Crown Estate have agreed that it would be appropriate to review the arrangements for assessing, granting and regulating marine fish farm leases". In response to this paper, the Crown Estate issued its own statement, welcoming the review and making it clear that CEC had never regarded this role as a permanent one. Indeed there have been indications that the move by the Scottish Office was prompted by a request from CEC. This review is the subject of a promised Scottish Office consultation paper (see section 8).

### Recommendation

5.7 **SWCL welcomes the long overdue review of the arrangements for assessing, granting and regulating marine fish farm leases. We recommend that the consultation process be initiated as a matter of urgency.**

# 4 INTRODUCTION

4.1 Despite the many appeals over the past decade from a wide range of bodies and agencies for strategic planning of the Scottish fish farming industry, this has failed to materialise. The case for such planning is highlighted by the rapid growth of the industry; the richness and sensitivity of the environment in which it operates; its still poorly understood impacts on that environment; the many different users of the coastal waters and the dependence of fragile coastal communities on industry that is sustainable.

4.2 However, the Government has no clear statement of policy on marine fish farming that addresses its social, economic and environmental objectives. The industry has remained free to operate and expand, effectively restricted by little more than its own technical and economic limitations.

4.3 Since SWCL's last review in 1990, the salmon farming industry has undergone major changes in terms of its structure and its aspirations. It has also experienced a series of crises, some economic, caused by international over-production, and some operational caused by the problems of intensification and growth such as disease. Throughout, the Government has remained largely silent. Despite its insistence of the importance of the industry, the Government has produced no strategic guidance for its development, referring to it only at the margins of other policy documents, such as, most recently, *Scotland's Coasts* (SOAEFD 1996b). Indeed, very little has changed in terms of development control or regulation of the industry.

# 5 CROWN ESTATE'S CONFLICT OF INTERESTS

5.1 The Crown Estate Commission (CEC) maintains its dual role of regulator of marine fish farming and landlord of the sea bed. As regulator, CEC essentially controls the number, siting and scale of fish farms by issuing sea bed leases, to which conditions covering aspects of gear type and site management are attached. As landlord, CEC is bound by its principal duty to "maintain and enhance the value [of the Estate] and the return obtained from it". This duality has been widely criticised as representing a conflict of interests and has led to innumerable calls for the responsibility for development control to be removed from CEC (see section 10).

5.2 The Crown Estate's administration of sea bed leases for aquaculture essentially has not changed since the introduction of the consultation procedure in 1986. This involves the circulation of copies of applications for sea bed leases (giving basic information on location, species and size of fish farm) to a range of interested bodies and nearby fish farmers, and publication of a formal notice in a local newspaper. Comments are required by CEC within 28 days. In the event of an application being refused, the applicant has a right to make representations but there is no right of appeal on the part of objectors. Some of the current salmon farm sites predate the introduction of CEC's consultation procedure. These leases were issued without proper consideration of the implications of the development and were routinely given for longer periods than the 15 to 20 years usually granted now.

5.3 The rate of lease applications that are consulted on has changed during recent years gradually declining between 1990 and 1994, but starting to increase again in 1995. Some of

6.6 The process of Environmental Assessment, which should form an essential element of the development control process and inform strategic planning, has been wilfully avoided by CEC. Its non-implementation has been ignored by the Scottish Office. The current review of the process for granting and regulating marine fish farm leases should provide the opportunity to ensure environmental assessment becomes an integral part of the planning process. It should also allow the role of Competent Authority for environmental assessment to be allocated to a body that will take the process seriously. SWCL considers the appropriate body to oversee the environmental assessment process to be SEPA, which has a broad responsibility for environmental protection and should have the ecological expertise to assess the potential impact of developments.

### Recommendations

6.7 **The Scottish Office should ensure the Environmental Assessment Regulations are fully and immediately implemented for fish farm developments, without delay, while the amended legislation is under consideration.**

6.8 **We recommend that SEPA be identified as the Competent Authority for EA, working in close consultation with the planning authorities and SNH.**

6.9 **Realistic and precautionary thresholds must be set to trigger the full mandatory environmental assessment process, that reflect cumulative impact as well as that of the individual development and the sensitivity of the area.**

## 7 CROWN ESTATE'S ADVISORY COMMITTEE

7.1 The Advisory Committee to the Crown Estate was established after an announcement by the Secretary of State in 1988, to resolve contentious applications for new sea bed leases. However, since then only two cases have been referred to the Committee. In both of these recommendation was to grant the lease (SOAEFD 1996).

7.2 Few cases have been referred to the Advisory Committee largely because consultees such as SNH do not tend to press objections unless they feel they have a very robust case. In particular, SNH faces difficulties where its concerns are based on the potential cumulative impact of developments in a given body of water, on which there is little published information. Such concerns demand a strategic approach rather than the existing site by site procedure. As a result, objections tend to be restricted to very obvious, demonstrable cases, such as conflicts with wildlife colonies (D. Donnan SNH pers. comm.). It has also been observed by consultees that CEC will go to great lengths to avoid using the Advisory Committee.

7.3 In short, the functioning of the Crown Estate with regard to development control of marine fish farming seems not to have improved since the last SWCL review in 1990. SWCL's previous criticisms of CEC's role and its approach to this responsibility still stand.

# 6 ENVIRONMENTAL ASSESSMENT

6.1 One of the most clearly evident failings of the Crown Estate's involvement in fish farming has been its role as the Competent Authority with responsibility for the implementation of the Environmental Assessment (Salmon Farming in Marine Waters) Regulations 1988. In this role, CEC has the power to decide whether a proposed development is likely to have a significant impact or not and thus whether to trigger the EA procedure. Since these regulations were introduced only one fish farm development has been subject to a full EA. The standard of the procedure conducted in this case was so low that it was the subject of a formal complaint to the European Commission (SWCL 1990).

6.2 Not one single further case has gone through the EA procedure, even though the size thresholds, set out in CEC's own guidelines and which were previously criticised for being too high, are now regularly being met. The Crown Estate's own explanation of this situation is that "so far all the salmon farming proposals have been below the size/location criteria for EA on submission or after reductions to resolve objections, or have been acceptable to the conservation consultees" (P.McGovern CEC pers.comm.). This comment illustrates the extraordinarily loose interpretation placed on the EA regulations by CEC. In practice, their approach has often been to pursuade applicants to reduce their proposals to just below the threshold area in order to avoid EA.

6.3 SNH, along with other official consultees such as Highland Council, have requested on numerous occasions that proposals be subjected to full EA but these have not been taken forward by CEC. The Crown Estate claims environmental consideratons are included in the assessment of every fish farm application. However, it is clear the totally inadequate data provided in a standard application makes proper assessment impossible and SNH has had to request EA in an increasing number of cases. More recently, some of these requests have resulted in the provision of additional environmental information. SNH has advised CEC that an EA is expected to support an application when the CEC's own guidelines are exceeded (D.Donnan SNH pers. comm.).

6.4 Ongoing discussions between SNH, SEPA and the industry are exploring the type and level of information required in order to assess the potential environmental impact of proposed developments. It is intended these will result in the agreement of a standard format for the provision of environmental information in support of lease applications (W.Crowe SSGA pers. comm.).

6.5 The Environmental Assessment Directive 85/337EEC has recently been amended (March 1997) and will have to be implemented within two years of its adoption. This will require reconsideration of the current implementing regulations, including those applying to intensive fish farming, which is an Annex II operation. Under the Directive the need for an assessment of such operations can be determined either on a case-by-case basis or through thresholds or criteria, as previously used by CEC. However, the new Annex III of the Directive lists selection criteria that must be taken into account. These include not just the size of the project, as previously considered, but also cumulative effect with other projects, waste production and risk of accidents. Consideration must also be given to the sensitivity of the area likely to be affected, paying particular attention to, among other areas, coastal zones (EC 1997).

8.6 In short, despite the considerable amount of work already undertaken, the Scottish Office failed to produce any guidance on the strategic planning, development or regulation of the fish farming industry. Meanwhile, all concerned continued to operate without the benefit of strategic guidance. In the final analysis, this seems to have happened largely because of the dominance of economic interests.

### Scotland's Coasts – a Discussion Paper

8.7 In March 1996 the Scottish Office published a consultative paper, *Scotland's Coasts* (SOAEFD 1996), announcing the review to be conducted of the arrangements for assessing, granting and regulating marine fish farm leases (see 5.6). While the review is welcome, and long overdue, the signs are it will be far too limited in its scope, dealing primarily with the site application procedure. If this is the case, it will be a woefully inadequate response to the shortcomings of the current planning and regulatory provisions.

8.8 The Scottish Office has indicated it intends to produce guidance on marine fish farming following the current review (D.Dickson SOAEFD pers. comm.). However, the planning process cannot be conducted effectively without the context of an overall strategic development plan for the industry, a comprehensive and transparent process of environmental assessment and a strong and credible authority to set and enforce operational conditions.

## 9 STRATEGIC GUIDANCE

9.1 The Scottish Office has not taken responsibility for the production of any kind of strategic guidance for the salmon farming industry as a whole. However, in its own policy document, the Scottish Office concludes "the coast is a complex system which should be managed in an integrated way" and that "the most appropriate management unit is the whole coastal zone" (SOAEFD 1996).

9.2 The salmon farming industry has now initiated its own strategic assessment, which is being conducted by the consultants Environmental Resources Management (ERM) (W. Crowe pers.comm.). The project is due to look initially at the site planning process and then at environmental and economic sustainability.

### Recommendation

9.3 **The scale of the existing industry and projections for future growth mean the need for strategic guidance over the development of Scottish fish farming is as pressing now as it has been at any point in the industry's history.**
**The Government must produce clear strategic guidance for the development of the industry as a matter of urgency.**

# 8 SCOTTISH OFFICE ROLE IN PROVIDING STRATEGIC GUIDANCE

8.1 The legacy of the past decade is one of massive development of the Scottish fish farming industry that has taken place with no strategic framework, that has been poorly planned, inadequately assessed and under-regulated. These shortcomings have been highlighted to the Scottish Office on many occasions and it has responded by starting various initiatives, involving the investment of considerable amounts of work, detailed below. However, none of them has come to fruition, leaving the planning and regulatory bodies to operate in a policy vacuum.

## Guidance on location

8.2 In 1991, in response to considerable public criticism of the role of the Crown Estate and the lack of any meaningful strategic planning of the fish farming industry, the Scottish Office Environment Department produced a consultative draft guidance document on the location of marine fish farms (SOED 1991). Rather than addressing the fundamental reforms needed in the whole planning and decision-making process, this document was based largely on CEC's own guidelines. However, it did propose some important improvements.

8.3 The guidance proposed the extension of CEC's list of "Very Sensitive Areas" (VSA) from 25 to 44 sites. In these areas there would be a presumption against new fish farms and a formal environmental statement would be required for significant expansion of existing sites. It encouraged planning authorities to produce indicative guidance on the siting of fish farms at a Structure Plan level. It also proposed a tightening of the thresholds for formal environmental assessment of salmon farm proposals, adding a new threshold for VSAs (cage area of over 2000m²) and annual production levels, rather than just cage areas, for other sites (250 tonnes in enclosed lochs and 500 tonnes in open sea). Formal environmental statements would also be required for development proposals that fall below these thresholds but where the impact on the environment would be significant. The guidance also provided more meaningful specifications for the content of a formal environmental statement.

8.4 This guidance document was never finalised. Scottish Office staff suggest that by the time the consultation was to be issued the surge in growth in the industry was already over, rendering the guidelines obsolete and no longer addressing the current needs. However, other consultees consider that siting guidelines with Scottish Office backing would have been extremely useful. Indeed, given the number of sites and the scale of developments that existed by this stage, it was argued that the need for guidelines was as great or greater than before. It has been suggested the guidelines would have caused considerable difficulty for CEC, increasing the demands of its regulatory role.

## Fish farming and the environment

8.5 A further consultation document was drafted by the Scottish Office entitled "Fish Farming and the Environment" as a Rural Framework policy paper. This document was never taken beyond a draft of February 1993. Scottish Office staff suggest this document was shelved due to anxieties in SOAFD regarding "additional regulatory pressures" being placed on the fish farming industry at a time when it was already facing marketing difficulties as a result of Norwegian competition. It is also notable the Scottish Office was conscious that concerns about the environmental impacts of fish farming appeared to be receding.

10.7 Local planning authorities should conduct this planning function in close collaboration with SEPA, as the Competent Authority for Environmental Assessment, and in statutory consultation with SNH and other relevant departments and agencies.

10.8 All applications for new fish farm sites and modification of existing sites should be required to contain adequate information on the nature of the area and of the proposed development to be able to determine the likely environmental impact.

# 11 REGULATION OF FISH FARMING OPERATIONS

## Self regulation

11.1 The industry has placed a great deal of emphasis on its ability to regulate its own operations, through producer associations, codes of conduct and now through various product quality assurance schemes. However, numerous reports of bad practice, including the illegal use of chemicals, mass fish escapes, wildlife destruction and site fouling, suggest that self-regulation has not, to date, been wholly successful.

11.2 Several schemes have emerged in recent years that seek to promote consumer preference for labelled salmon products. The largest is the Tartan Quality Mark scheme, with members predominantly from the mainland and Western Isles. Shetland Seafood Quality Control is run by Shetland Islands Council. Another small scheme was launched recently by the salmon smoking company, Ghillie and Glen, in conjunction with the Guild of Conservation Grade Producers and working with producers in Orkney. The larger schemes are concerned mainly with the product, covering such aspects as flesh quality, hygiene and treatment residues. Although some of these features have a bearing on the environmental impact of production, the environmental performance of the operations is not specified directly. The Soil Association is currently developing standards for organic farmed fish which would place greater emphasis on environmental and welfare standards. In addition, the Marine Stewardship Council, launched by WWF and Unilever in 1996 with the aim of setting standards for, and ultimately labelling, fish caught in ecologically sustainable fisheries, is now considering extending its scope to aquaculture operations. For any of these schemes to have credibility they must be

# 10 PLANNING CONTROL

10.1 Major criticisms have been made repeatedly over the past 10 years over the suitability and performance of the Crown Estate in the role of development control authority for the marine fish farming industry (SWCL 1988; SWCL 1990). Indeed, of the bodies giving evidence to the House of Commons Agriculture Committee's enquiry into fish farming in 1990, 21 out of 27 were critical of CEC's planning role (Warren 1991). Beyond its conflict of interests (see section 5) these criticisms include CEC's lack of strategic overview, its lack of democratic procedure and transparency in decision-making, inadequate provision of information, lack of expertise to assess environmental impact and lack of consideration for conservation designations.

10.2 These criticisms have led many commentators, including Highland and Strathclyde Regional Councils and the Western Isles Council, to call for improved planning controls for the industry (SWCL 1988). In 1987 the Convention of Scottish Local Authorities (COSLA) demanded that planning control, which otherwise applies only down to low water mark, be extended to marine fish farming, adding that this was essential if such developments are to be integrated successfully with other coastal activities. Benefits predicted to arise from such a change include the ability of local authorities to assess individual proposals, not just on a case-by-case basis but in the context of a hierarchy of policies and forward plans, from local and structure plans through to national planning policy guidelines (NPPGs). In addition, the long established and democratic planning system would ensure more open access to information and more transparent decision-making (SWCL 1988). Despite its lack of formal powers, Highland Regional Council took the initiative of producing a strategy document on fish farming development and a series of Framework Plans for affected areas in 1988.

10.3 The Government has resisted these calls for the extension of planning control for fish farming. Its justification has been based largely on the argument that such a move would require new primary legislation and that all sorts of other marine activities would then also be brought under local planning authority control (Warren 1991). Other concerns raised about the option of extending planning control include the potential for inconsistency between the various authorities over planning decisions and the danger of local economic considerations influencing decisions unduly to the detriment of other interests.

10.4 However, the situation in Shetland illustrates that such a system can be workable. The Zetland County Council Act 1974 imposes a duty on the council to conserve and control development in coastal areas. This Act requires fish farmers to apply for a Works Licence, which is advertised and open to public representation in the same way as normal planning permission. There is a right of appeal to the Secretary of State, which extends to objectors as well as applicants (Warren 1991).

### Recommendations

10.5 **In order to achieve a more democratic process that takes proper account of ecological constraints and the needs of sustainable development, we recommend that the powers of local planning authorities be extended to include responsibility for planning decisions on the siting of marine fish farms.**

10.6 **We recommend that local planning authorities continue to take a strategic overview regarding the future of marine fish farming in their areas by means of inclusion in structure plans, based on the national strategic guidance.**

transparent, rigorous and open to scrutiny in terms of the criteria applied and the procedures of assessment and certification. While market-led schemes can complement mandatory regulation, none currently fulfils these needs.

## Mandatory regulation

11.3 The replacement of the Crown Estate in its regulatory role and the establishment of SEPA provide the opportunity for major changes in the way fish farming operations are regulated and operational conditions are set and enforced. In April 1997 SEPA issued a consultation paper on the regulation and monitoring of marine cage fish farming in Scotland (SEPA 1997) which sets out options for its potential role as a regulatory body and standards that should be applied.

11.4 The remit of SEPA is primarily to provide an integrated environmental protection system for Scotland that will contribute towards sustainable development. In order to achieve this SEPA is tasked to consider sustainable development from a long term perspective, to promote improved technologies and management techniques and to conserve and, where practicable, enhance biodiversity and protect the natural heritage. The breadth of this remit makes SEPA the appropriate body to regulate the operation of the salmon farming industry once planning consent has been given in order to ensure its environmental impact is kept to a minimum. Clearly, such a role would need to be closely integrated with that of the planning authorities and would require liaison with, and co-ordination of the relevant functions of other agencies and authorities such as SNH and SOAEFD in discharging their statutory duties.

## Recommendations

**11.5 We welcome the initiative taken by SEPA to address the future direction and regulation of the fish farming industry and to consult widely in this process.**

**11.6 We recommend that SEPA be charged with the role of regulating the operations of the industry, insofar as they are relevant to its environ-mental impact; conducting or co-ordinating, as appropriate, functions relating to the control of waste, medicine and chemical discharges, and impacts on wild fish and other wildlife. It should have the powers to set and enforce standards relating to fish health, husbandry and site management in consultation with other relevant bodies such as SOAEFD and SNH.**

**11.7 We recommend the establishment under SEPA (in collaboration with SOAEFD, HSE and other appropriate authorities) of a unified monitoring body with a vessel based capacity to monitor and police the operations of the industry.**

**11.8 We recommend that this regulatory function be conducted in a transparent fashion, with public access to conditions that are being applied and to monitoring data.**

**11.9 We further recommend the Scottish Office makes adequate resources available to SEPA to conduct this important and expanded regulatory role with credibility.**

# PART III

## IMPACTS

### HUSBANDRY AND POLLUTION

Summary

Problems experienced by the industry in terms of disease and poor fish survival are forcing changes in husbandry and fish farm operations that should also help to alleviate their environmental impact. However, these beneficial effects may be over-ridden by the massive increases in the amount of fish being produced at farms.

Solid waste pollution from feed and faeces has been considered a localised problem below farms, but is now recognised to have more far reaching effects. Recovery of the sea bed once a farm has been removed takes around two years and this process is hindered by the presence of antibiotics. Soluble waste, in the form of dissolved nutrients may have profound effects on sea loch and coastal ecology, potentially increasing primary production and the risk of toxic algal blooms. Nutrient balance is further disrupted by antibiotics from salmon farms and potentially also by the use of toxic chemicals such as sea lice treatments.

SEPA's powers to control pollution from fish farms are limited largely to the discharge consent procedure. However, in fulfilling its remit to provide an integrated environmental protection system to contribute towards sustainable development, SEPA is charged to promote improved technologies and management techniques.

SWCL proposes that:

- Site management such as stocking and fallowing should be subject to regulations, formulated by the industry and SEPA to protect seabed, sea loch and fish health;
- SEPA should resist the current trend towards massive increases in site tonnages and set precautionary limits on production levels;
- The Government should withdraw its reservation to an internationally agreed recommendation (PARCOM 94/6) on reduction of inputs of toxic chemicals from aquaculture and introduce legislation to increase SEPA's regulatory powers with respect to fish farming operations in line with principles of the IPPC Directive.

# 12 HUSBANDRY

12.1 At the operational level the Scottish salmon farming industry has undergone considerable changes during the early to mid-1990s, largely as a result of two general features: high fish mortality, associated with disease and poor siting and husbandry; and increasingly marginal economics, associated with poor productivity and prices depressed by over-production internationally. These factors forced changes in fish farm operation to improve fish survival and profitability if companies were to survive.

12.2 The most pressing problems that have driven changes in farm practice are disease, most notably furunculosis, and sea lice infestation. Between them, these factors were responsible for the extremely high level of salmon mortality experienced in the early 1990s (SOAFD 1992 & 1993) and also the high levels of chemical treatments used by the industry (see sections 15 & 16). The incidence of both disease and parasites is strongly influenced by the suitability and management of the farm site, determining, for instance, the pollutant loading and resultant stress to the fish (see section 13), and the risk of cross-infection. These problems have been addressed to some extent by improved husbandry measures, some of which are outlined below.

## Site fallowing

12.3 The extreme disease problems experienced by the industry led SOAFD to strongly recommend fallowing of sites for as long as possible to allow year class separation for disease control purposes. However, in 1991, an "unacceptably low" level of 29% of sea cage sites were fallowed, compared with 97% of fresh water sites. In 1992 "an encouraging" 21% increase in the number of fallowed sea sites was reported. In 1993, 63% of sites were fallowed for periods that ranged from just a few weeks to over a year. In 1994, 35% of sites were reported as fallow for varying numbers of weeks, while 29% of sites were fallow, or "not in production" for the whole year. SOAFD noted that the number of sites still not fallowing remained a concern. In 1995 the number of sites fallowed for some period increased to 43%, while 26% reported no production at all that year (SOAEFD 1992-1996).

## Site selection and rotation

12.4 While site fallowing is primarily conducted to break any cyclical disease that might be present, there is now also recognition of the need to remove fish in order to "rest" or "cleanse" sites. This is intended to allow the sea bed to recover from the build up of pollutants, particularly solid waste and potentially pathogens, that contribute to stress and mortality in fish. The level of pollution at a site depends largely on its physical nature and the way it is managed. Recent research suggests that even when taken out of production, sites take around two years to recover to their normal condition (DML Annual Report 1995-96) (see also 13.4).

12.5 The trend towards siting salmon farms in less confined waters suggests fewer sites are now operational where fish health would be compromised by the polluted state of the sea bed and which would not be considered economic. The abandonment of such inappropriate sites would be welcomed. While there are large sites still being used in sheltered lochs with poor flushing, there appears to be a move to use these temporarily or on a rotational basis.

## Reduced food waste

12.6 Recent developments in fish feeds towards the use of more easily digestible organic compounds have increased feed conversion efficiency. This can reduce the levels of waste accumulating on the sea bed. However, the shift to high oil diets also results in much of the waste material being excreted in liquid form with an increase in the release of dissolved organic compounds. The effects of this on the environment are largely unknown (Folke et al 1994).

12.7 While more efficient feeding is clearly in the interest of companies, it is not clear how widespread good feeding practice is within the industry. Figures on current food conversion rates have not been provided for Scotland. However, reports of the Norwegian industry suggest there has been a recent decrease in the food conversion rate, with the result that over 1.5 tonnes of feed are used to produce one tonne of salmon, compared to just 1.2 tonnes used a few years ago. It is reported this shift may be attributable to the increased use of automated feeding systems (Shetland Fishing News, February 1997).

## Increased stocking biomass

12.8 Notwithstanding the improvements in site use and husbandry mentioned above, the potential benefits, in terms of fish health and environmental protection, may be jeopardised by the recent massive increase in the amount of fish, or biomass, held at sites. This is associated with an increase in waste products and risk of disease and parasite episodes. In addition to the trend towards overall increases in site biomass, the latest generation of fish cages are substantially larger in size, some having surface dimensions of 30 m by 30 m with nets 20 m deep (W.Crowe pers.comm.). These cages have a volume eight times greater than the largest cages in use in 1987.

12.9 Stocking densities of fish within the cage are reported to have been reduced. Whereas the target maximum density used to be 25-30kg/m$^3$, recent practice has been to aim for a maximum of about 15kg/m$^3$ (FAWC 1996). However, it has been observed that, since the reduction in stocking densities has been introduced primarily to control disease, the increasing use of vaccines may lead to a further increase in stocking density. In a study of the welfare of farmed salmon, signs of fish injury were taken as indicating stocking densities that may still be too high (FAWC 1996).

12.10 The total production capacity of sea cages remained broadly static during the period from 1992 to 1994, despite 19 less sites being used. SOAFD noted that while not reflecting stocking density directly, the figures suggest stocking per unit volume had increased. SOAFD cautioned "farmers should reflect that the currently highly effective controls on disease will eventually fail if this process is continued" (SOAFD 1995).

12.11 Given the potential risks to fish survival associated with high stocking biomass, it is paradoxical that much of the increase observed in recent years has been the result of improvements in fish survival and growth. Also, after several years of declining or static numbers of smolt being put to sea, 1994 saw an increase of 1 million smolts (5%) on 1993, indicating optimism amongst salmon growers (SOAFD 1995).

12.12 It could be that the benefits of the current trend towards site fallowing and rotation are being offset by, or are even providing something of a smoke screen for, massively increased site sizes and stocking biomass.

## Recommendation

**12.13 The stocking densities of fish, the size and proximity of cages, the overall stocking biomass, and management of sites with regard to fallowing and rotation should be reviewed and subject to regulations, formulated by the industry and SEPA, to protect seabed and sea loch health and to reduce the risk of disease and parasites.**

# 13 POLLUTION–WASTE

## Solid waste

13.1 It has long been known that the build up of waste food and faecal products beneath fish farms can cause major changes to the sea bed and its ecology (Gowen & Rosenthal 1993). The degree of change depends largely on the physical and hydrographic features of the site, the scale and intensity of production at the salmon farm and sensitivity of the feeding regime.

13.2 Solid wastes generally lead to organic enrichment of the sea bed, which can result in the accumulation of increasingly thick, black and anoxic sediments. This enrichment can also lead to oxygen depletion in the water column (Gillibrand et al 1996). In more heavily polluted sites the sediment becomes covered with a characteristic white mat of the bacterium Beggiatoa sp. and various processes of anaerobic decay of the organic matter lead to the release of ammonia, hydrogen sulphide, carbon dioxide and methane from the sediment (Black et al 1996; Davies et al 1996). Hydrogen sulphide production is of particular concern because of its toxic properties, including to the salmon. Continued use of such "soured" sites has been associated with deterioration of fish health and a decline in productivity, and in some cases has resulted in sites having to be abandoned.

13.3 Whereas earlier research (Gowen et al, 1988) detected no effects beyond 30 to 40 m from farms, more subtle effects of enrichment have been detected up to 100 m from the cages in some locations (Weston 1990). A more recent study of the effects of sedimentary changes in Loch Ailort, where salmon farming operations have continued for over 20 years, suggests the symptoms of organic sediment enrichment may be far more widespread. (Gillibrand et al 1996).

This study concluded that sediments throughout much of the loch may contain high levels of organic carbon and that up to 50% of this load may be contributed by fish farm food. Loch Ailort is considered typical of Scottish sea lochs in terms of its physical and hydrographic features, and has a reasonably frequent replacement of water, flushing on average every eight weeks. However, the study found that water in the deeper basin of the loch (below 20m) was stagnant, with high levels of dissolved nutrients and low oxygen levels in the bottom water. This was considered to be the result of the breakdown of organic matter in the sediments by bacteria and to be indicative of organic enrichment.

13.4 A four year Benthic Recovery Programme was completed by Dunstaffnage Marine Laboratory (DML) in 1995, funded by the SSGA, DTI and the feed manufacturer Trouw Aquaculture. The objective of the study was to determine the optimum period of site fallowing to allow sea bed recovery for the purposes of farm management. A descriptive model of biological communities at marine fish farms was produced and tested at three sites, with varying conditions and degrees of fouling. These were fallowed at the beginning of the project and the sediment chemical processes and benthic communities were then monitored over three years. The sites took around two years to recover to normal communities (DML Annual Report 1995-96). The results of this study are not yet available and may not be published until 1998 (K.Black DML pers.comm).

13.5 The effective breakdown organic waste on the sea bed is totally dependent on an active community of benthic bacteria. However, it is recognised that the use of antibiotics to treat diseases on fish farms may have important impacts on this community (see also 15.2). These include effects on the rates of bacterial processes, the composition of bacterial populations and on the level of antibiotic resistance in these populations (Davies et al 1996). Experiments indicate that antibiotics suppress the level of bacterial activity in sediments, although the extent of this effect depends on factors such as the growth rate of the bacterial population and the proportion of resistant bacteria (Davies et al 1996). The effects of antibiotics were also studied as part of the Benthic Recovery Programme conducted by DML which indicates that the presence of antibiotics is a major factor affecting the rate of recovery after the cessation of fish farming (DML Annual Report 1995-96).

13.6 A further project at DML, funded by Scottish Natural Heritage (SNH), looked at the effects of various methods proposed by the industry for assisting the recovery of the benthos from salmon farm pollution. Techniques considered include harrowing the sea bed, using bacterial culture and enhancing the population of capitellid worms. A preliminary assessment of the results suggests that the interventions produced no significant improvement, except for the enhancement of capitellid worms which showed some benefits in lightly impacted conditions. Contrary to anecdotal evidence, harrowing actively exacerbated conditions at some loadings, as did bacterial culture (DML Annual Report 1995-96). However, due to delays in sediment analysis, the full results of this work are not expected to be published for some time (K.Black pers.comm).

### Soluble waste

13.7 The generation by salmon farms of substantial quantities of dissolved nutrients, mainly in the form of nitrogenous wastes (ammonium and urea) and phosphate, and the potential impacts these may have on coastal waters have been a matter of concern for many years. An assessment of the potential for large-scale enhancement of nutrient levels, or hyper-nutrification, suggested this was unlikely at the existing level of farming (Gowen & Ezzi 1992). However, increases in the concentration of ammonia in near surface waters have been recorded in Loch Hourn, associated with the operation of a fish farm (Gowen & Ezzi 1992). Also the increased nutrient status of a sea loch basin has been attributed to a fish farm (Gowen & Rosenthal 1993; Gillibrand et al 1996).

13.8 The potential relationship between nutrient inputs from aquaculture, increased primary production leading to eutrophication, and the risk of toxic algal blooms has been raised in a number of commentaries (Gowen & Bradbury 1987; Gowen & Ezzi 1992; Berry 1996). Anecdotal evidence from Norway of an increase in phytoplankton production resulting from fish farming activity has been cited (Gowen & Rosenthal 1993). As many algal blooms are harmful to fish, either by causing anoxia through the decay process, clogging the gills, or through the production of toxins (Bruslé 1995), such events could have potentially serious consequences for the fish farming industry itself, commercial fisheries, as well as the ecology of the area.

13.9 It has been assumed that as the proportions of nitrogen and phosphorus released in fish farm effluents (a ratio of 10.6:1) are close to those naturally occurring in near-surface waters, these discharges are unlikely to disrupt this nutrient ratio of sea lochs (Gowen & Ezzi 1992). However, it is now recognised that the discharges from aquaculture may affect the nutrient ratios and this can result in alterations in the composition and character of the microbiota such as bacteria and microalgae. In Sweden, changes in nutrient ratios as a result of aquaculture inputs are cited as likely causes for the development of a variety of algal blooms (Folke et al 1994).

13.10 Recent speculation has raised the possibility of a link between such changes in nutrient ratios and the apparently increasing incidence of paralytic shellfish poisoning (PSP) in Scottish coastal waters since the late 1980s (Berry 1996). The organisms responsible for the PSP events in Scotland have not yet been identified but they have been explained as the result of "naturally occurring algal blooms… not linked with pollution" (Scottish Office News Release 23.6.93). However, the incidence of algal blooms has been directly correlated with coastal pollution or utilisation of coastal waters for aquaculture (Anderson 1989).

13.11 Research has also shown that changes in the nutrient balance in the water column may be disrupted further by the use of antibiotics by salmon farms. Results indicate the group of antibiotics tested, the potentiated sulphonamides, may cause a massive increase in the release of phosphate from sediments (Provost et al 1996; Davies et al 1996). Given that these antibiotics also inhibit the release of ammonia, the net effect is likely to be a shift in nutrient ratios.

13.12 Furthermore, in an assessment of the impact of nutrient enrichment of Scottish sea lochs, it has been noted that the greatest effects are seen as a result of a reduction in grazing rates by zooplankton (Ross et al 1993). Such a reduction can occur as a result of an artificially-introduced toxic source, grazing inhibitory substances produced by microalgae or anoxic conditions. The authors conclude that when such a reduction in grazing is combined with a situation of nutrient enrichment, there is potential for a serious environmental problem. A number of toxic sources are introduced by the fish farming industry, most notably in the form of sea lice treatments such as dichlorvos, which is known to be toxic to a range of zooplankton and has been used in large quantities and at high frequency over the past

10 years (see also 16.2). Therefore, it seems reasonable to suggest that a reduction in grazing rates may have been experienced in some areas, further exacerbating changes in the nutrient balance and potentially disrupting the ecology of coastal waters.

### Recommendations

13.13 **Given the importance of research findings on benthic recovery and the impacts of antibiotics on the benthos to the management and regulation of salmon farm operations, these results should be made available by the SSGA to SEPA and other relevant bodies at the earliest opportunity.**

13.14 **The relationships between discharges from salmon farms, the nutrient balance in sea lochs and coastal waters and microbiotic communities needs to be investigated as part of an inter-agency research effort, led by SEPA and involving the Scottish Office Marine Laboratory. In particular, the role of nutrient fluxes in the incidence of algal blooms and production of biotoxins should be examined.**

13.15 **In line with the precautionary principle, the potential effects on benthic and nutrient processes of antibiotics and toxic chemicals used by salmon farms should be given greater consideration by SEPA in the formulation of policy and consent procedure for the discharge of such substances.**

## 14 CONTROL OF POLLUTION

14.1 Control of pollution from fish farms is conducted by the Scottish Environment Protection Agency (SEPA) which was established in April 1996 under the Environment Act 1995. SEPA took over this role from the River Purification Boards (RPBs) and Islands Councils. Discharge consents are issued under the Control of Pollution Act 1974, involving a process of public advertisement and consultation. However, discrepancies in policy and practice between the various authorities persisted up to, and in some respects since, the establishment of SEPA. The variation in requirements for monitoring of sites and consenting of discharges has resulted in inconsistent standards being applied and major differences in the data held between the different regions.

### Site monitoring

14.2 Monitoring required prior to discharge consent being issued for a new site in Highland region required a sea bed survey, accompanied by a sea bed video to determine the energy level of the site. Sites were subsequently self-monitored with an annual sea bed video required for low energy sites, which might be checked by HRPB audit samples (HRPB pers.comm). Clyde RPB required sediment samples and hydrographic data for new sites, including 15 days' current recordings for larger sites. Similar data were required for proposals to increase the tonnage of a site. Prior monitoring could also lead to substantial reduction of the biomass consent from that requested (CRPB pers.comm). Shetland Islands Council operated a system of sea bed survey, based on transect sampling. New sites required the submission of a survey report with photographic and written descriptions in order to establish the sea bed type. Annual self-monitoring was conducted by repeating the standard sea bed survey which could be checked by an independent assessment (SIC pers.comm).

14.3 Although occasional sea bed and salmon samples have been analysed for ivermectin and other treatments of concern, none of the authorities conducted regular monitoring of sites for antibiotics, ivermectin or any of the other chemicals in use.

## Discharge consents

14.4 Consenting of discharges has also varied between regions. HRPB appears to have consented any licensed chemicals that were requested without setting quantity limits, except in the case of dichlorvos (see 16.2.6). Annual inspections of site records were made but no reports of discharges were required from the farms. Although CRPB did not specify individual chemicals in discharge consents, regular reports were required from farms of their maximum biomass and treatments used. SIC gave consent for each chemical that was requested. In theory they could require prior notice of use but this was not practised. Details of chemical usage were gathered by annual questionnaire. Clearly this did not constitute an adequate system for monitoring discharges.

14.5 In order to estimate the enhancement of nutrient and chemical levels arising from salmon farms within sea loch systems, the Scottish Office Marine Laboratory has developed a series of computer models (Gillibrand & Turrell 1995). Three simple models address nitrogen balance within a loch, inputs of the sea lice treatment dichlorvos over a year, and concentration levels of dichlorvos arising from such inputs. A further, more complex model has been developed that addresses the physical oceanography of various sea lochs to test the underlying assumptions of the simple models.

14.6 These models are designed to ascertain whether environmental quality standards (EQS) are exceeded by the fish farms within a loch system (Gillibrand & Turrell 1995). However, few EQSs have been set for substances discharged by the industry. Highland RPB adopted a maximum nitrogen level, which was specified in consent conditions, of 300μg/litre of which no more than 50μg/litre should be ammonia (at least 50m from the cages). An EQS of 40μg/litre has been assumed for dichlorvos (Gillibrand & Turrell 1995). These models have been used to determine the maximum fish biomass allowed in a water body, given assumed inputs of nitrogen and dichlorvos per tonne of fish produced.

14.7 A statutory EQS for dichlorvos of 40μg/litre (annual mean concentration in coastal waters) has been proposed for England and Wales and is expected to be adopted in 1997 (DoE 1997a). This move has not yet been taken in Scotland. However, it is now acknowledged that substances which are toxic, persistent or liable to bioaccumulate have the potential to cause long term damage and there are inherent uncertainties in predicting the effects of long term, low-level exposure (DoE 1994a). These features make EQS an inappropriate strategy for such substances, which should be controlled by input reduction and prevention.

## SEPA's commitments

14.8 In the past, pollution control policy on fish farming was coordinated to some extent by the Cage Fish Farm Technical Group of the Association of Directors and River Inspectors of Scotland (ADRIS). However, practice was still fragmented and inconsistent between regions. Pollution control functions are now being unified under SEPA, whose Fish Farming Advisory Group (FFAG) has within its remit:

- to devise strategies and methods of regulating and monitoring discharges from fish farms, and to standardise the application of methods throughout Scotland;
- to develop methods for controlling pollution due to fish and shellfish farming, and to predict changes in water, sediment and biological quality at the planning stage;
- to consider and make recommendations on quality objectives and standards for areas affected by fish and shellfish farming, and for chemicals used in such farming; and
- to consider and advise on, environmental problems which may arise from fish and shellfish farming.

A consultation paper on the regulation and monitoring of the marine cage fish farming industry in Scotland has recently been issued by the FFAG (SEPA 1997a).

14.9 The Government guidance on SEPA and Sustainable Development (Scottish Office 1996) states that the principal aim of SEPA is "to provide an efficient and integrated environmental protection system for Scotland which will both improve the environment and contribute to the Government's goal of sustainable development". An essential element of sustainable development is stated to be "conserving and where practicable enhancing biodiversity and protecting the natural heritage". Specific principles underlying the approach to sustainable development include the precautionary principle and the "polluter pays" principle.

### SEPA's powers

14.10 SEPA's existing powers under the Control of Pollution Act are limited. For instance, the interpretation of its consenting powers has been strictly related to water quality considerations (SEPA 1997a). The legislation apparently limits the definition of management practices that can be prescribed to those that have a direct bearing on discharges. Thus, the requirement of husbandry techniques that reduce disease or sea lice levels and therefore the discharges of chemotherapeutants, may fall outside SEPA's powers.

14.11 This limited legislation contrasts with the provisions of the more recent Environment Protection Act 1990 relating to integrated pollution control (IPC). This at present covers only the larger polluting industries, such as chemical production, but allows stipulation of standards of management. It also contrasts with the Secretary of State's guidance to SEPA on sustainable development which specifies that regulation should be clear and consistent and promote improved technologies and management techniques.

14.12 Various international developments may provide guidance for increasing SEPA's regulatory powers with regard to marine fish farming. The EU Directive on Integrated Pollution Prevention and Control (IPPC) was adopted in September 1996. This legislation has a more holistic approach to the regulation of prescribed processes through application of best available techniques. It covers, for instance, pollution prevention, energy efficiency, noise production and the reinstatement of sites. However, although intensive agriculture is covered by the directive, aquaculture is not.

14.13 In 1994, the Paris Commission (PARCOM), which oversees the Paris Convention 1974 on the protection of the North Sea and North East Atlantic, made a recommendation (94/6) covering the reduction of inputs of potentially toxic chemicals from aquaculture use (PARCOM 1994). This recommends that national authorities draw up codes of best environmental practice to cover measures including: limitation of the density of fish in cages; management agreements between neighbouring fish farms for disease and parasite control; the use of wrasse for sea lice control; avoidance of the prophylactic use of chemicals; washing and drying of nets instead of use of toxic antifoulants and fallowing periods to permit sea bed recovery. The UK Government adopted a reservation to this recommendation, thus exempting itself from its obligations.

## Recommendations

14.14 **SEPA should ensure the requirements adopted for prior assessment and monitoring of salmon farm sites for sea bed and water quality are the highest standards, rather than the lowest common denominator of those previously operated.**

14.15 **The EQS approach should not be used for substances that are toxic, persistent or liable to bioaccumulate. Where the EQS approach is applied, for instance for nutrient inputs, SEPA should demonstrate that standards adopted are precautionary and open to scrutiny, the process of assessing compliance transparent and consistent, and the regulations enforceable.**

14.16 **In line with the "polluter pays" principle, SEPA should charge the industry as necessary to meet the costs of effectively conducting these monitoring, regulatory and enforcement duties.**

14.17 **In light of SEPA's duty to further sustainable development and given the poor state of knowledge on the effects of current or increased salmon production levels on the ecology of Scottish waters, SEPA should resist the current trend towards massive increases in site tonnages and set precautionary limits on production levels.**

14.18 **The Government should withdraw its reservation to PARCOM 94/6 at the earliest opportunity and introduce legislation to increase SEPA's regulatory powers with respect to fish farming operations in line with principles of the IPPC Directive.**

# MEDICINE AND CHEMICAL USE


## Summary

The intensive production of farmed salmon is associated with both disease and parasite problems that have caused major losses to the industry. The use of antibiotics and chemotherapeutants is therefore widespread.

Extreme disease problems in the early 1990s led to very high levels of antibiotic use in fish feed, causing increasing levels of antibiotic resistence in the bacteria. Once in the marine environment, the antibiotics are still active and can cause resistence in other non-target bacteria species, with implications for human health. They are also persistent, with little or no degradation occurring in sediments where they may persist for months or even years. Antibiotics also suppress the decay of organic matter, thus affecting sea bed recovery under cages. The development of increasingly effective vaccines has now reduced the levels of antibiotic use.

Sea lice present another major problem for the industry and affect most farms. These parasites are treated mainly using chemotherapeutants, which are either poured into the enclosed fish cage and then released after the treatment, or incorporated into the salmon feed. Sea lice treatments are, by their nature, biocidal and have raised considerable concern over their impact on other non-target species and the ecology of the marine environment. Resistance to treatments has also been encountered in sea lice. Four substances are currently authorised and a succession of further chemicals is being considered or developed for use.

Several non-chemical methods of sea lice removal have also been developed. The use of wrasse as cleaner-fish that feed on the lice has had reported success but has been largely rejected by the Scottish industry. Considerable effort is going into the development of a sea lice vaccine but this may be up to 10 years away.

With the use of increasingly large fish cages, the application of chemical antifoulants to prevent growth on cage nets is again causing concern, particularly with regard to levels of copper being released into the environment.

SWCL proposes that:

- The environmental impacts of antibiotics should be given greater consideration and SEPA should adopt a more precautionary approach to their release;
- SEPA and the industry should promote non-toxic means of sea lice control, such as cleaner-fish, and the development of alternative methods for sea lice removal;
- SEPA should adopt a clear presumption against the continued reliance on toxic therapeutant and chemical use and place more emphasis on the prevention of sea lice, disease and fouling problems by the introduction of stringent requirements on husbandry and site management practices.

# 15 DISEASE CONTROL

## 15.1 Prevalence of disease

15.1.1 Given the intensive conditions under which farmed salmon are reared, coupled with the increasing scale of operations and the proximity of many sites to each other, it should not come as any surprise that disease has presented major problems for the industry. Diseases have caused serious losses, accounting for the mortality of almost half of the stock put to sea in some years (SOAEFD 1993b). Some, most notably furunculosis which posed the greatest disease problem in 1990, have now largely been contained.

15.1.2 Under the Diseases of Fish Acts 1937 and 1983 certain diseases in salmon have to be notified to SOAEFD. These include the bacterial diseases furunculosis and bacterial kidney disease (BKD), and the viral disease infectious pancreatic necrosis (IPN) (SOAEFD 1990b). Any reports of these notifiable diseases are investigated by the Scottish Office Marine Laboratory who then advise on appropriate action to be taken. For instance, the imposition of Designated Area Orders restricts the movement of infected stock.

15.1.3 The Scottish Office disease records should be interpreted with caution for a number of reasons. Although they provide the frequency of outbreaks they do not give any indication of the severity of disease events such as the number of fish affected. Only newly diagnosed cases are listed, so they do not indicate diseases that carry over from one year to the next. Neither do the records include cases that were handled by veterinarians or other diagnostic services that may not have been notified to the Marine Laboratory. Legally it is the responsibility of the fish owner or proprietor to report notifiable diseases to SOAEFD. Reports of the diagnostic cases submitted to the Marine Laboratory were published annually up to 1992 (SOAEFD 1990-1993b) but were then discontinued to avoid the risk of misinterpretation. These figures for selected diseases are given in Table 1, along with those provided for 1996 (T. Hastings, Marine Lab. pers.comm).

**Table 1. Diagnostic cases of selected diseases submitted to the Marine Laboratory from sea water sites of the Scottish salmon farming industry 1989-1992 and 1996**

| | 1989 | 1990 | 1991 | 1992 | 1996 |
|---|---|---|---|---|---|
| Furunculosis | 127 | 124 | 80 | 41 | 1 |
| BKD | 11 | 8 | 5 | 0 | 0 |
| Vibriosis | 45 | 20 | 10 | 13 | 34 |
| IPN | 75 | 123 | 142 | 105 | 24 |
| Pancreas disease | 34 | 52 | 18 | 20 | 1 |

*source SOAEFD*

15.1.4 Since the introduction of EC Directive 91/67 and the UK Fish Health Regulations in 1993 much of the Marine Lab's work has been concerned with maintaining the UK's disease free status for List II virus diseases: viral haemorrhagic septicaemia and infectious haematopoietic necrosis. This requires regular inspection and testing of every registered fish farm in the country as well as wild fish. Six inspectors aim to make at least one or two pre-arranged visits to each farm per year including examination of its health records (T. Hastings pers.comm.).

## 15.2 Antibiotics

15.2.1 Antibiotics are commonly used on salmon farms for the treatment of bacterial diseases, such as furunculosis. The very serious prevalence of this disease during the early 1990s resulted in widespread and routine administration of antibiotics in salmon feed. The use of antibiotics in marine finfish culture and their potential environmental effects were reviewed by Spencer in 1993.

15.2.2 Four classes of antibiotics are licensed for treatment of farmed salmon: oxytetracycline, oxolinic acid, potentiated sulphonamides and amoxycillin. In addition to the seven licensed products available in 1993, two new antibiotics are now licensed: Aquatet (oxytetracycline) and Micromox (amoxycillin) (Veterinary Medicines Directorate pers.comm).

15.2.3 A major challenge for the industry has been to "keep ahead" of antibiotic resistance, which develops as a result of continuous use of one drug or ineffective treatment. This problem has been particularly acute in the control of furunculosis. In 1991 approximately 14% of furunculosis cases were found to show some degree of resistance to all four drugs tested, 16% to three, 24% to two and 42% to one drug. Of the pathogens examined only 3% were found to be fully sensitive to all four drugs and these were mainly from wild caught fish (SOAEFD 1992). Of the furunculosis bacterium isolates that were examined in 1995, 50% were resistant to oxytetracycline and 66% to oxolinic acid (A. Munro Marine Lab. pers.comm.) and there has been a corresponding decrease in the use of these drugs (see Table 2). However, use of the more recently licensed amoxycillin has increased and levels of resistence of furunculosis pathogens to this drug rose to 35% in 1996 (A. Munro pers.comm.).

15.2.4 Antibiotics can pass through the fish cages into the marine environment in a still active form, either as uneaten medicated feed pellets or in fish faeces. They then become available to be eaten by other marine fauna, leach into the water column or are deposited on the sea bed (Spencer 1993). This widespread release of potent antibiotic compounds into the marine environment arouses a number of concerns.

15.2.5 Oxytetracycline and oxolinic acid have been found to persist in sediments for months, with some 10% still present seven months after administration. Further deposition of waste residues over the drug-containing layer increases its persistence even further (Samuelson 1992). A half-life of 419 days was recorded for oxytetracyline in the sediment at one particularly stagnant site (Bjorklund et al 1990). More recent evidence indicates oxytetracycline and oxolinic acid do not degrade at all in sediment (Samuelson et al 1994) and that the loss rates observed for these compounds are the result of other mechanisms, such as resuspension or dissolution. It has also been found that antibiotics suppress the microbial activity in sediments (Jacobsen & Berglind 1988; Davies et al 1996), affecting the process of aerobic degradation of organic sediments and, thereby, sea bed recovery under fish cages (see also 13.5).

15.2.6 Acquired resistance may occur in other non-target bacterial species. A study of fresh water trout farm sites found increasing numbers of antibiotic-resistant bacteria, and a decrease in the numbers of antibiotic-sensitive species. (Austin 1985). The chance of bacterial resistance developing in fish pathogens in the sediments has been identified as a potential source of fish disease problems (Samuelson 1992). Given the widespread and growing resistance of human pathogens to antibiotics and the potential for such pathogens to be contracted both directly from sea water and via fish and shellfish, the public health implications of antibiotic use in fish farming cannot be over-looked.

15.2.7 The use of antibiotics is regulated by veterinary prescription under the Medicines Act 1968. No central record is kept of levels of prescribed use and the River Purification Boards (and Islands Councils) did not place limits on the quantities of antibiotics discharged. Also, the reporting of these discharges varied considerably between regions. Clyde RPB (now SEPA West Region) required salmon farms to make regular returns of the amount of each consented substance used and, therefore, has a fairly comprehensive database of the inputs reported by fish farmers. In contrast, Highland RPB (now part of SEPA North Region) did not require annual returns from fish farmers, mindful that they would not necessarily be an accurate reflection of what was actually used. Instead, HRPB relied on inspection of the farms' own records. In theory sites were visited once or twice per year but in practice limited resources meant visits were less frequent, especially in the islands (A.Rosie SEPA pers.comm.). Thus, SEPA North does not have a full set of records of antibiotic use.

15.2.8 An indication of the scale of antibiotic use by the industry can be gained from the SEPA West data, which is presented for the years 1991 to 1996 in Table 2. It should be noted that in these years the production of salmon in the West Region represented roughly 20% of the total Scottish production (SOAEFD 1992-1996a). Assuming that use of antibiotics is fairly uniform across different regions, the whole industry could be expected to be using around five times the totals reported by fish farmers for SEPA West Region. Taking the peak year of 1992, an estimate of the total antibiotic use in Scottish salmon farms would be in the region of 22 tonnes. Since then the overall use of antibiotics has decreased, reflecting the increasing level of resistance of bacteria to the drugs (see 15.2.3) and the increasing use and effectiveness of vaccines (see 15.3).

**Table 2 Antibiotics (kg) reported to be used by salmon farms in SEPA West Region**

| | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 |
|---|---|---|---|---|---|---|
| oxytetracycline | 705 | 1561 | 1170 | 561 | 772 | 144 |
| oxolinic acid | 273 | 503 | 674 | 109 | 468 | 89 |
| pot.sulphonamides | 1401 | 1315 | 1094 | 1209 | 751 | 223 |
| amoxycillin | 602 | 993 | 842 | 747 | 854 | 1116 |
| total | 2981 | 4372 | 3780 | 2626 | 2845 | 1572 |

*source: SEPA (west region)*

15.2.9 Comparable figures for antibiotic use in human medicine and in terrestrial livestock treatment are not held centrally in the UK. However, these figures are available in Norway. The mean annual consumption of antibiotics in the Norwegian salmon farming industry, which is some three times larger than Scotland's, in the early 1990s was 29 tonnes. The figure for antibiotic use in traditional veterinary and human medicine over this period averaged 10 and 25 tonnes respectively per year (SFT 1993). Reported antibiotic use in Norwegian salmon farming has since been greatly reduced, to 1037 kg in 1996 (Norwegian Medicinal Depot pers.comm.).

15.2.10 The MAFF Veterinary Medicines Directorate (VMD) has routinely tested farmed salmon for residues of all the licensed antibiotics since 1992. In 1992, 24% of salmon samples from UK retailers contained residues of oxytetracycline, almost half of which were produced in Scotland. At that stage no Maximum Residue Limits (MRLs) were set for fish so results merely reflect detection of the drug. In 1994, 1% of salmon samples tested contained oxytetracycline above the MRL set for this drug (100µg/kg). In 1996 six cases out of 275 samples of farmed salmon tested (over 2%) were found to contain oxytetracycline levels above the MRL (VMD 1993-1997).

15.2.11 SEPA West data also indicate that an unauthorised antibiotic, Furazolidone, was being used by salmon farms at least until 1992. This antibiotic was banned by the EC in 1995 (regulation EC/1442/95). SEPA West Region's listing of registered chemicals for salmon farms in 1996 still included Furazolidone as a chemical that can be used as long as its use is reported in monthly biomass and chemical returns, although no applications for consent have been received since 1992.

### Recommendation

15.2.12 **Although the use of antibiotics by fish farms has dropped substantially, discharges are still highly significant and their impacts on the environment and health are not adequately considered. SEPA should adopt a far more restrictive and precautionary approach to the release of antibiotics by fish farms.**

## 15.3 Vaccination

15.3.1 The observed reduction in the use of antibiotics since the early 1990s is probably associated most closely with the development of more effective vaccines and their increasing use, in conjunction with improved site management and fallowing practices (see 12.3). The widespread development of antibiotic resistance in the furunculosis pathogen Aeromonas salmonicida increased the urgency of developing an effective vaccine against this disease in the early 1990s, which was funded largely by the SSGA. Several vaccines for furunculosis are now on the market and the number of fish vaccinated, usually prior to smolting, has increased each year. In 1994, 85 sites vaccinated a total of 20.7 million smolts against furunculosis (out of 21.5 million put to sea) (SOAFD 1995a). In 1995 furunculosis vaccination was carried out at 102 sites (SOAEFD 1996a).

15.3.2 The increasing prevalence of IPN, identified at 44% of tested sea sites in 1990, stimulated research into a vaccine against the causal virus (SOAEFD 1991b; 1994b). No vaccine is available against BKD but work is reported on the nature of the bacterium that will be useful in vaccine development (SOAEFD 1993b; 1994b). The other major area of vaccine development work is for sea lice (see 16.8.8).

# 16 SEA LICE CONTROL

## 16.1 Prevalence of sea lice

16.1.1 Sea lice infestations, caused mainly by the copepod *Lepeophtheirus salmonis* and to a lesser extent the smaller *Caligus elongatus*, have continued to present a major problem to the salmon farming industry. Most Scottish farms are known to be infested with sea lice (McVicar 1994). However, as sea lice infestation is not a notifiable condition, no official records are collected on the frequency or extent of outbreaks.

16.1.2 Sea lice are parasites that can cause serious damage through their feeding activity on the skin of their salmon hosts (Wootten et al 1982). In severe cases lesions often found on the head may result in the skull being exposed and death can occur through osmoregulatory failure. Although sea lice occur on wild fish, this is usually in small numbers and epidemics are rare (however, see section 24 on sea lice and sea trout). In fish farms sea lice numbers tend to increase over time, eventually reaching epidemic proportions and causing the serious problems experienced where intensive salmon farming has been established for many years (Roth et al 1993). Sea lice are also thought to have contributed to the seriousness of many furunculosis outbreaks by weakening fish, by spreading the disease from the skin lesions they cause and by moving from fish to fish (SOAEFD 1990b).

16.1.3 The cost of sea lice to the industry, in terms of fish losses and treatments, has been estimated at £22 million per year (W. Crowe pers.comm.). The importance of sea lice to the salmon farming industry is also indicated by the level of research effort that has been focused on developing effective treatment methods. Some of these developments have been reviewed in Spencer (1992). The use of the organophosphate dichlorvos was strongly opposed by environmentalists but was the only therapeutant licensed for sea lice treatment until hydrogen peroxide came into use in 1993. Ivermectin is reported to have been in illegal use in Scotland since 1991 (Daily Telegraph 8.7.91) but fresh controversy was raised when ivermectin was granted discharge consent by SEPA in 1996. The organophosphate azamethiphos also gained marketing authorisation in 1996. Further research by pharmaceutical companies is ongoing to get other treatments onto the market. In addition, various types of physical lice removal have been explored and a major research programme has been in progress since the late 1980s to develop a sea lice vaccine.

## 16.2 Dichlorvos

16.2.1 Aquagard SLT© (Sea Lice Treatment), previously marketed as Nuvan© (active ingredient: dichlorvos), is manufactured by Novartis (which was Ciba-Geigy until February 1997). In June 1989 Aquagard was granted a product licence for one year under the Medicines Act 1968. This licence was renewed for two more years in June 1990, in view of the industry's dependence on dichlorvos. This was despite the Government's identification of dichlorvos as a "red list" or priority hazardous substance, and its obligation under the 1987 North Sea Conference agreement to reduce inputs by 50% from 1985 levels by 1995. Aquagard currently has a standard product licence, which is only subject to the routine five year review process (VMD pers.comm).

16.2.2 The toxic effects of the organophosphate, dichlorvos, have been well documented elsewhere (eg. Ross 1989; Spencer 1992). However, it is worth mentioning here more recent research findings on the sensitivity of lobster larvae to the chemical (McHenery et al 1991), toxicity of dichlorvos to marine phytoplankton (Raine et al 1990), reduced sensitivity in non-target species, and sublethal effects in the invertebrate community (Robertson et al 1991). Interestingly, when the use of dichlorvos was being developed in the 1970s it was suggested the amount of active ingredient released into the environment could be substantially reduced (by up to 90%) by increasing the pH of the solution after treatment. However, this practice was not adopted as the industry did not take up the use of special enclosed pens for treatment of sea lice (Roth et al 1993).

16.2.3 Resistance of sea lice to dichlorvos was detected by the early 1990s, especially at sites with prolonged and heavy use of the substance (Jones et al 1992). The obvious implication of resistance is reduced efficacy of the treatment which would require increased dose rates and exposure times. However, as this would also increase the risk to the fish, this makes the use of the dichlorvos impractical (Roth et al 1993). The other important implication is the potential for cross resistance to other organophosphorus compounds.

16.2.4 Since it is a prescribed veterinary medicine, there is no central record kept of the quantity of dichlorvos used and it is difficult to estimate. However, Scottish Office Marine Laboratory figures suggest that in 1989 the industry used 0.292 kg of dichlorvos per tonne of consented production (Gillibrand & Turrell 1995). Production of salmon in 1989 was 32,350 tonnes, which suggests that use of dichlorvos was almost 9.5 tonnes. However, as resistance to dichlorvos has become widespread there has been a drastic reduction in the use of this chemical against sea lice.

16.2.5 SEPA, and previously the River Purification Boards and Islands Councils, require reports of usage of dichlorvos which are summarised in Table 3 for the two main SEPA regions covering fish farming (North and West).

**Table 3. Quantities (kg) of dichlorvos (active ingredient) released from marine salmon farms 1990 – 1996**

| | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 |
|---|---|---|---|---|---|---|---|
| North | 5913 | 3827 | 2440 | 2584 | 1892 | 876 | – |
| West | – | 1915 | 1575 | 899 | 637 | 394 | 212 |
| Total | – | 5742 | 4015 | 3483 | 2529 | 1270 | – |

– data not available

*source: SEPA (North and West Regions)*

16.2.6 In response to the Government's commitment to halve inputs of dichlorvos by 1995, HRPB estimated the baseline load for the region to be 4486kg, based on the first available data from 1988 and 1989 (HRPB 1995). In addition to the reductions in dichlorvos use as a result of sea lice resistance, HRPB introduced a policy of not consenting the discharge of dichlorvos at any new farm sites and, where possible, reducing the discharge load for existing sites. One site has since been prosecuted and fined £1000 for exceeding its consent limit for dichlorvos (SEPA North pers.comm). Similar reductions in dichlorvos use have been recorded in what is now SEPA West Region.

16.2.7 In addition to concerns about its environmental impact, the use of dichlorvos also raised growing concern about the health implications for fish farm operatives handling the substance. As an acetylcholinesterase inhibitor, dichlorvos can cause both acute and cumulative toxic effects on the human nervous system. It has also been reported that fish farms have experienced problems with availability of Aquagard. Novartis explains this by the reduction in demand which means they now only produce Aquagard to order (A. Stewart, Novartis pers.comm.).

### 16.3 Ivermectin

16.3.1 Ivermectin is a broad spectrum parasiticide used extensively to treat cattle, pigs, sheep, goats and horses. It is available in several formulations licensed under the names Ivomec© and Oramec© (MSD-AGVET, a division of Merck Sharp and Dohme). These products can be bought over the counter without prescription from agricultural merchants and veterinary practices. However, ivermectin is not licensed for the treatment of fish and until the summer of 1996 discharge consents were not being issued for its use. Prior to this, any use in Scottish fish farms was illegal and a fish farmer in Wester Ross has been prosecuted for its use (Spencer 1992).

16.3.2 Ivermectin is a semi-synthetic member of the group of compounds known as avermectins, which are macrocyclic lactones. It has a low solubility in water and a high tendency to become bound to sediments. Ivermectin is administered to fish as a coating on the feed. However, it is very slowly absorbed in the fish gut and is excreted mainly in its active form (Hõy et al 1990). Ivermectin is also toxic to aquatic organisms at extremely low levels (Spencer 1992). Recent research suggests ivermectin, which is expected to accumulate in sediments, is likely to cause significant mortality to polychaete worms which play an important role in the breakdown of waste matter. It is therefore predicted that the build up of ivermectin will slow the breakdown of organic matter below fish cages and exacerbate the pollution load with potentially deleterious effects on fish health (K. Black et al 1997).

16.3.3 Early trials on the efficacy of ivermectin against sea lice infestations were conducted in Ireland where its use is now widespread. It is common knowledge that ivermectin has also been used widely in fish farms in Scotland and particularly in Shetland. Residues in Shetland-produced salmon have been detected by Shetland Seafood Quality Control (SSQC, an independent body run by the SIC Development Department) although it reports that none was detected in the previous year (SSQC, pers.comm). It is worth noting that although SSQC detected illegal residues of ivermectin, of which SIC was aware, no action was taken by the Environmental Health Department to prosecute the offenders (SIC pers.comm).

16.3.4 Residue testing by MAFF Veterinary Medicines Directorate (VMD) of farmed salmon from retail outlets found ivermectin in 5% of samples tested in 1993, in 11% of samples in 1994 and 3% of samples in 1995 (VMD 1994-1996). The VMD has no legal authority to trace samples back to the producer and the industry argues that some of the salmon sampled may have originated from outside Scotland. However, the individual results are reported back to the retailer from which the sample was obtained and to the SSGA. It is assumed that this process results in market pressure on the industry to improve its performance (J.Kay, VMD pers.comm). While the results may suggest a reduction in the use of ivermectin, they may equally signify that ivermectin is still in use but with more regard to withdrawal time prior to harvest so it is no longer detectable in the salmon. It was recently reported that two retail chains, Tesco and Marks and Spencer, have announced they will not continue to stock salmon treated with ivermectin (Scotsman 30.4.97). This decision was attributed to concerns not only about potential residues in the fish but about the environmental impact of ivermectin.

16.3.5 In 1993, MSD introduced a new formulation, Ivomec Premix for Pigs©, which is administered in feed. This changed the legal status of ivermectin as a potential treatment for sea lice. This is because the veterinary regulations allow a product to be used for other species if it is administered via the same route for which it is licensed. This use has to be under veterinary prescription and various other conditions, known as the "cascade" (see 16.3.12). Thus from 1993, the only legal barrier to the use of ivermectin has been the need for consent to discharge the chemical under the Control of Pollution Act 1974. In the summer of 1996, SEPA North granted the first discharge consent for commercial use of ivermectin on a salmon farm.

16.3.6 The decision by SEPA to consent the discharge of ivermectin was a highly controversial one. It arose after several years of work by the SSGA with the Cage Fish Farm Technical Group of ADRIS to devise a programme of studies to examine the environmental implications of ivermectin use in salmon farms. SSGA funded this work which was conducted by the Scottish Office Marine Laboratory and other independent labs. Field trials were also conducted at two sites under special discharge consents.

16.3.7 The laboratory studies found crustaceans to be extremely sensitive to ivermectin. In addition, the lugworm Arenicola marina is killed at very low concentrations and shows significant sublethal effects, to feeding and burrowing activity, at even lower concentrations (MAFF 1995). The toxicity of ivermectin to this important sediment reworker reinforces concerns about its effects on breakdown processes beneath salmon farms. The researchers concluded that degradation of ivermectin in sediments is slow, with a half-life of well over 100 days (Bennet et al 1995a).

16.3.8 A further study found that mussels exposed to ivermectin in sea water for six days bioaccumulated the compound by a factor of 752. Their depuration rate once placed in clean water was estimated to have a half-life of 22 days (Bennet et al 1995b).

16.3.9 The results of the laboratory and field studies have been reviewed for the SSGA by Inveresk Research International (McHenery 1996). The field results have not yet been published but have recently been made publicly accessible by SEPA.

16.3.10 These findings were considered by the ADRIS Technical Group, which was superceded by the Fish Farming Advisory Group of SEPA, in April 1996. Their conclusion was that they could not reasonably refuse to grant discharge consents for ivermectin. However, this ruling was qualified by a number of conditions as follows:

- it should be reviewed in two years;
- there should be a clear code of practice for preparation and application;
- there should be an exclusion zone of two nautical miles around shellfish farms;
- more data is required to be collected on methods of analysis of ivermectin to improve detection, dispersion, effects of chronic exposure and residues in sediments and mussels.

16.3.11 However, serious concerns remain about the toxicity of ivermectin to marine organisms and the inadequacy of data held on the chemical's fate and persistence in the environment. These led SWCL and others to object to SEPA's decision to grant discharge consent for ivermectin and to make a formal request to the Secretary of State for Scotland to reconsider this decision. In addition to environmental concerns, objections have been lodged by shellfish farmers, not reassured by the two-mile exclusion zone, and by fishermen, whose fish and shellfish catch is offered no protection by this condition.

16.3.12 The decision to allow the use of ivermectin on salmon farms is also questionable in terms of the legal provisions of the Medicines (Restrictions on the Administration of Veterinary Medicinal Products) Regulations 1994. These allow the application of a product to a species for which it has not been authorised if it meets certain conditions, known as the "cascade". The first condition of the cascade is that "no authorised product exists for a condition in a particular species". In the case of sea lice on salmon, there are several other authorised products: Aquagard (dichlorvos see 16.2), Paramove and Salartect (hydrogren peroxide see 16.4) and, since December 1996, Salmosan (azamethiphos see 16.5).

16.3.13 A further condition of the cascade limits its application to "a particular animal under [a veterinarian's] care or small number of such animals". Tens of thousands of salmon that would be treated in a farm cage or site, would not appear to constitute "a small number". Indeed, in 1989 a letter from the Presidents of the Royal College of Veterinary Surgeons and British Veterinary Association among others, reminded vets that "unlicensed medicinal products should only be used on one particular animal or small number of animals. A small number of animals does not mean a flock or herd or other similar group of animals". However, the VMD has since issued guidance to vets which states that in the case of farmed fish, all individuals in one cage may be regarded as equally at risk of an infection and, therefore, a "small number" may be interpreted to reflect this (VMD 1995).

16.3.14 As of January 1997, SEPA had received 100 applications from salmon farms for consent to use ivermectin, 15 of which had been granted and nine refused. Many of the remainder are the subject of call-in requests or are effectively "on-hold" pending the outcome of the Secretary of State's consideration. In the meantime, the rate of applications by farms has been lower than anticipated by SEPA, presumably because of the uncertainty surrounding the status of ivermectin. Applications are also being scrutinised more closely for consistency between regions and in terms of additional guidelines regarding the site, including the status of the macrobenthos and presence of shell fisheries such as Nephrops creeling (A. Haig SEPA pers.comm.). The industry states that ivermectin will only be used in exceptional circumstances and until another product is authorised. It claims that even if the whole industry were to use ivermectin it would only amount to some 5 kg per year (W. Crowe pers.comm).

16.3.15 The legal status of ivermectin looks likely to change again with the introduction in 1997 of a new EU regulation. This will require all veterinary products to have a Maximum Residue Limit (MRL) set for each species for which they are used. Establishing an MRL is an expensive process that can prove prohibitive in the case of minor species. Given the relatively small number of treatments authorised specifically for salmon and carrying an appropriate MRL already, the salmon farming industry is opposed to this change in the law. However, the precise requirements and deadlines of the regulation are still under discussion (VMD pers.comm.).

16.3.16 The manufacturers of ivermectin, MSD Agvet, have made it clear they have no interest in obtaining marketing authorisation for ivermectin for this relatively marginal use in aquaculture. However, as the patent for ivermectin expires in 1998, any other company will be free to manufacture and market or seek authorisation of the drug. The SSGA has expressed an interest in getting ivermectin authorised for use in salmon (W. Crowe pers.comm), although the costs and benefits of pursuing this course of action will presumably be determined largely by progress in the development of other treatments. Meanwhile, MSD Agvet has recently announced a novel ivermectin has been selected with chemical and biological attributes it considers make it an appropriate product for use as a sea lice treatment in the marine environment. This new compound is being jointly developed with Schering Plough, which specialises in products for aquaculture. The companies expect to complete the regulatory dossier for the product in 1997 (MSD Agvet correspondence to RSPB 4.3.97).

## 16.4 Hydrogen peroxide

16.4.1 Hydrogen peroxide is used as a bath treatment in a similar fashion to dichlorvos, with use of a 50% w/v hydrogen peroxide formulation at a concentration of 1.5 g per litre for 20 minutes described by Roth et al (1993). Efficacy is reported to be good against adult and pre-adult stages of lice although there seems to be some speculation that the compound works mechanically through the generation of oxygen bubbles which knock the lice off the salmon, thus allowing reinfestation (T. Wall, Fish Vet Group pers.comm.). However, removal of attached stages of lice by this process would presumably result in their death.

16.4.2 In common with several other sea lice treatments, hydrogen peroxide is reported to be toxic to salmon. Toxicity increases with temperature and causes damage which appears to be restricted to the gills (Roth et al 1993). However, as the breakdown products of hydrogen peroxide are oxygen and water, the need to oxygenate the confined fish is reduced thus reducing one stress factor of treatment. More importantly, the compound does not persist in the environment, and is therefore assumed to cause limited ecotoxicological impact and no toxic products.

16.4.3 Two hydrogen peroxide products are currently available for sea lice treatment: Paramove© (Solvay Interox) and Salartect© (Brenntag UK Ltd). These products were used under Animal Test Exemptions since 1992 and given full authorisation in 1995 and 1996 respectively (VMD pers.comm). The SSGA considers hydrogen peroxide to be highly effective and states that some 80% of the industry has used it (W. Crowe pers. comm.).

16.4.4 Despite the efficacy of hydrogen peroxide, it is not popular with the industry, largely because of the high cost and large quantity of the chemical required, making treatment a very labour intensive process. The industry also argues that treatment with hydrogen peroxide is a risky process for the fish, which tend to get highly concentrated in the raised pen in order to reduce the amount of chemical needed to reach the correct concentration. There are claimed to have been major fish kills as a result of hydrogen peroxide treatment (T. Wall pers.comm.), although it is not clear whether these were caused by the toxic nature of the chemical or the stress of the treatment process. However, only three incidents of suspected adverse reactions to hydrogen peroxide, affecting a total of 3500 fish, have been reported to the VMD (VMD pers.comm.). This means that if there are serious problems with the treatment that militate against its use, they are not being officially recorded. Apparently it is not unknown for fish farmers to fail to report adverse reactions to a treatment for fear of the authorisation being withdrawn (T. Wall pers.comm.).

16.4.5 SEPA does not limit the amount of hydrogen peroxide used or require prior notice of treatment. Records of use are only available for SEPA West Region where 11 tonnes were reported to be used in 1993, rising to 127 tonnes in 1994 and 328 tonnes in 1995. However, in 1996 reported use of hydrogen peroxide in SEPA West Region had fallen back to 64 tonnes (A. Haig pers. comm.). This reduction is more likely to reflect the increasing use of other new treatments than a reduction in the incidence of sea lice. In Shetland, by contrast, no farms appear to have requested discharge consent for hydrogen peroxide. It is considered there to be too expensive and too risky for both the handlers and the fish. Hydrogen peroxide is reported to be used widely in the Faroes, but with a mobile squad of specially trained and equipped operatives (D. Okill, SEPA pers. comm.).

## 16.5 Azamethiphos

16.5.1 Azamethiphos is a broad spectrum organophosphorus pesticide, similar to dichlorvos in its action and also produced by Novartis. The product, Salmosan©, is a bath treatment that is produced in powder form (whereas Aquagard is a liquid). It is packaged in a water soluble bag which is dropped directly into the mixing container to minimise handling before being released into the fish cage. Salmosan was given an Animal Test Certificate in the UK in 1992, went through field trials in Scotland and was awarded a marketing authorisation by the VMD in December 1996. Applications for discharge consent are currently being considered by SEPA. Azamethiphos is already used extensively in Norway, where it was authorised in 1995, and it was also given emergency authorisation in 1996 for use in Canada (A. Stewart pers. comm.).

16.5.2 Azamethiphos is to be used at a concentration of 0.1 ppm, one tenth of the concentration used for dichlorvos (1 ppm) which means that the compound is acutely toxic to sea lice at this lower concentration. However, the manufacturers state that azamethiphos is less toxic than dichlorvos to all the non-target species studied, with the exception of lobster larvae, to which it has the same toxicity. The half-life of azamethiphos is reported to be the same as for dichlorvos (around seven days in the marine environment) (P. Dobson, Novartis pers. comm.).

16.5.3 Novartis has had to produce a substantial amount of data on the nature and effects of azamethiphos in order to meet the VMD's safety criterion. The ecotoxicology research was conducted for Novartis by the Scottish Office Marine Laboratory but this data has not been published. Under the terms of the Medicines Act, the company is protected by a vigorously applied commercial confidentiality clause which means no data has to be disclosed. Novartis has stated it does not intend to publish this information, at least until the discharge consent has been granted (P. Dobson pers. comm.)

16.5.4 Given that azamethiphos acts by the same mechanism as dichlorvos (inhibiting the neurotransmitter acetylcholinesterase) there is expected to be some cross-resistance such that sea lice which are resistant to dichlorvos may also be resistant to azamethiphos (P. Dobson pers. comm.). This effect has already been demonstrated in field trials (Roth et al 1996). At two out of the three test sites, lice were found to have reduced sensitivity to azamethiphos prior to treatment which resulted in the efficacy of the treatment varying from 85% or better at the sensitive site, to means of 57% and 69% at the resistant sites. This means that commercial use of azamethiphos may prove not to be effective, or that fish farmers may be tempted to use more of the chemical to increase its effect.

16.5.5 In 1994 the ADRIS Technical Group considered the use of azamethiphos as a sea lice treatment and concluded that discharge consent would be refused. SEPA now acknowledges that the concerns previously expressed about the environmental risks associated with azamethiphos remain. However, it has indicated new treatment proposals suggest that at some sites, controlled use of the substance may be possible without breaching tentative environmental quality standards. SEPA therefore considers a blanket policy of refusing to consent the discharge of azamethiphos would be difficult to justify (SEPA 1997b). It remains to be seen how many consents will be issued and under what conditions.

## 16.6 Cypermethrin

16.6.1 Cypermethrin is a synthetic pyrethroid, based on the structure of pyrethrum, the natural insecticide contained in chrysanthemum flowers, but with a higher biological activity and stability. It is widely used as an insecticide on crops and in animal husbandry, such as sheep dips. The manufacturer, Grampian Pharmaceuticals, has formulated the product Excis© as a bath treatment for sea lice. Excis is currently under Animal Test Certificate and has undergone extensive field trials. The manufacturer expects the product to be granted a marketing authorisation by the VMD in the near future, pending the establishment of an MRL and a withdrawal period for salmon. It is also under consideration by SEPA for discharge consent.

16.6.2 Cypermethrin is most toxic to crustacea and, unusually, adult lobsters are more sensitive than the larvae. Acute toxicity in some species occurs well below the treatment concentration of 5 ppb (compared with 2 ppm for dichlorvos), which means less of the compound needs to be used but also gives an indication of its extreme toxicity. Its toxic action is on sodium channels in nerve membranes, disrupting impulses. The main attraction of Excis is that, unlike most other treatments, it is effective against all developmental stages of sea lice, theoretically requiring less frequent treatments (J. Braidwood, Grampian Pharmaceuticals pers.comm.). Grampian Pharmaceuticals report treatment intervals of five to six weeks in field trials, compared with two to three weeks required with the organophosphate azamethiphos.

16.6.3 The manufacturer reports that Excis has been formulated specifically to promote initial dilution and dispersion and then rapid binding to particulates, in which state it has vastly decreased toxicological action. Field studies have been conducted at 12 sites in Scotland, including one site that had eight treatments over a two year period. These investigated effects of the product on various non-target species and found high mortality (up to 100%) of shrimps and lobsters within the treatment cages but lower mortalities (one shrimp out of nine) outside. Sub-lethal effects of lethargy and other "slight effects" were found in shrimps deployed in the plume of Excis as it was released from the cage.

16.6.4 Although no residues were detected in the sediments at trial sites, the fate of the chemical in the environment has not been determined. The effects on potentially vulnerable groups such as micro-zooplankton have not yet been studied. In addition, no follow-up studies have been conducted into subsequent health or reproductive effects in exposed animals. This latter omission is particularly important because the synthetic pyrethroids have been identified as hormone (or endocrine) disrupting compounds (Lyons 1996). The adverse effects caused by such compounds, particularly on the reproductive system, can occur at far lower concentrations than would be identified by normal toxicity testing, but can produce long-term and profoundly damaging effects to wildlife, ecosystems and, potentially, humans.

16.6.5 As with Salmosan, the ecotoxicology data for Excis has been derived by and is the property of the manufacturer. Although data is made available to SEPA for consideration of discharge applications, Grampian Pharmaceuticals is under no obligation to publish this data and has stated it does not intend to do so as this, it argues, would be to the benefit of competitors (J.Braidwood pers. comm.). Thus there can be no open and public scrutiny of the information held on the effects of this product. It seems significant, however, that Excis has been used on a commercial level in the Faroes and Norway since early 1996 but no long term studies of the environmental effects have been undertaken.

## 16.7 Diflubenzuron and Teflubenzuron

16.7.1 Diflubenzuron and teflubenzuron are insect growth regulators that act by inhibiting chiton production, thus affecting the moulting cycle and lice development. A diflubenzuron product, Dimilin© (T.H Agricultural & Nutrition Co.), was evaluated with respect to sea lice control in Norway. It was administered orally to infected salmon at a dose rate of 75 mg per kg for 14 days and found to significantly reduce both adult and larval stages of lice. However, it was found to be extremely toxic to marine crustaceans at very low concentrations and to be relatively persistent in sediments, to which it binds tightly. Given these factors and the large quantities required to achieve effective treatment, this compound was considered unsuitable for sea lice control (Roth et al 1993).

16.7.2 A teflubenzuron product, Calicide©, has now been developed by Nutreco and is being promoted by its daughter company Trouw Aquaculture. It also produced under the trade name of Ektobann© in Norway. This is an orally fed treatment the manufacturers argue is extremely safe for fish, the operator and the consumer (Fish Farmer, Nov/Dec 1996). The withdrawal period for fish treated with Calicide has been set at 100 degree days. The company states that successful trials have been conducted in Norway and sea trials were conducted in Scotland in 1996 under Animal Test Certificate.

16.7.3 Although there is little ecotoxicity data available on this compound, the Safety Data Sheet for the teflubenzuron product, Nomolt, classifies it as dangerous for the environment, not readily biodegradable, very toxic to aquatic organisms and with the potential to cause long term adverse effects in the aquatic environment. Trials on the environmental effects of Calicide are continuing and Trouw Aquaculture believes the product should gain Marketing Authorisation in 1997 (R.Sinnott, Trouw pers. comm.). Both diflubenzuron and teflubenzuron have limited authorisation for use in Noway that will be re-evaluated after one year pending results on their environmental fate and effects (K. Fagernës SFT pers.comm.).

## 16.8 Other control methods

### Wrasse

16.8.1 Various species of wrasse (family Labridae) have been explored as potential cleaner fish to remove the sea lice from salmon since the late 1980s. Successful commercial trials have led to their widespread use, most commonly with goldsinny (*Cetnolabrus rupestris*), rock cook (*Centrolabrus exoletus*) and corkwing (*Labrus mixtus*). Indeed accounts of their performance suggest that wrasse may be more effective in controlling lice infestations than conventional chemical treatments. An additional benefit is that wrasse will clean fouled nets, although it has been suggested their preference for net fouling organisms may reduce their licecleaning efficiency. The optimum stocking ratio of wrasse to salmon appears to be about 1:50 and the minimum feasible wrasse size is 100 mm (Sayer 1996).

16.8.2 Over a third of salmon farms on the Scottish mainland and Western Isles are reported to have used wrasse in the years 1989-1994, using an estimated 150,000 wrasse (Treasurer 1996). This high turnover of wrasse is attributed to a combination of escapes and poor over-wintering and survival rates in the salmon cages. Most of these wrasse are caught from the wild, raising concerns about the potential impact on wild populations and the ecology of inshore waters in which wrasse play a significant role, both as predators and prey. There is also a risk of disease transfer via wrasse movement and escapes, to both farmed salmon and wild fish stocks.

16.8.3 These concerns about the exploitation of wild wrasse have led to the successful breeding and rearing of wrasse in captivity in both Scotland and Norway. Wrasse culture has the potential to provide a year-round supply of disease-free fish, and particularly for the introduction of smolts to sea cages in the spring. Wrasse that are introduced to salmon cages with, or just before, the new smolts, have been found to clean more effectively, and may even continue to clean the salmon right through to harvest (Young 1996).

16.8.4 Despite these reported successes with wrasse and the obvious ecological benefits of biological control of sea lice compared to the use of toxic chemicals, interest in wrasse within the Scottish industry appears to be waning. It appears that this position is largely determined by financial and efficiency considerations. An SSGA funded project to breed wrasse in captivity at the Sea Fish Industry Authority facility at Ardtoe was stopped after three years for not being cost-effective (W.Crowe pers.comm). A number of companies, including Marine Harvest McConnell, used wrasse on a commercial scale but argued they were effective only on smaller salmon. Apparently some farms are still using wrasse, but Marine Harvest McConnell which was taking up to 17,000 wrasse a year, is thought to have stopped using them (P. Smith, SFIA pers.comm). Local fishermen who had supplied wrasse are reported to have converted back to other fisheries.

16.8.5 In contrast, there is considerable interest and research in Norway on the use of wrasse and other cleaner fish as alternatives to chemical treatments, both for sea lice and anti-fouling. In 1995 some 350 salmon farms were using wrasse (K. Fagernës SFT pers. comm.). However, Norwegian use of wrasse appears still to be based on wild populations, which do not occur naturally in the northern parts of the country, creating difficulties in terms of supply and potentially the impact on wild stocks.

### Light, physical and sonic devices

16.8.6 The Lure is a device designed to attract lice by mimicking the shimmering effect of light reflecting off a salmon's scales. It consists of a structure about one metre tall with four light tubes at its core. The lice are attracted into the water around the lights which is then pumped to the surface where the lice are filtered out. The Lure was designed and is produced by the Scottish company Terecos, which states it is effective against all lice stages, but primarily attracts the copepodid stages. The company claims that in a closed test system the light lure proved 100% effective and trials have also been conducted in Loch Fyne. However, the SSGA's view of the Lure is that although it worked successfully in tanks, it is not effective in the field (W. Crowe pers.comm.).

16.8.7 A pump called the Silkstream™, which was designed for the transfer of fish from one cage or container to another, is now being marketed as a sea lice removing device. The manufacturers claim that sea lice removal rates vary from 35% to 100%, with mature lice being removed most effectively. The lice are apparently dislodged by the acceleration and deceleration of fish in the pump and are then filtered out of the water. Another sea lice removing device based on sonar is currently being developed by Ferranti-Thomson under contract to the SSGA (W. Crowe pers.comm.).

## Vaccine

16.8.8 Considerable research effort has been invested since 1989 into the development of a vaccine against sea lice. The main research programme has been conducted by the Scottish Office Marine Laboratory working with Aberdeen and Stirling Universities. The research is based on the successful African tick vaccine and involves recombinant proteins. These are produced by taking genes from the sea louse, adding them to bacteria and isolating the product. This is then tested for antibody stimulation in the salmon that would kill the sea lice. Apparently three antigens have been identified so far that cause the required effect, involving digestive and reproductive systems (W. Crowe pers.comm.).

16.8.9 Although the research has made some positive progress its funding is due to run out in mid-1997 (A. Munro pers.comm.). So far the project has had three separate EC grants, money from MAFF and SOAEFD, and over five years of funding from the SSGA. However, vaccine research is long and expensive. The development of the furunculosis vaccine took 10 years but the use of molecular engineering in the sea lice project adds additional work and expense. Although a number of commercial companies are interested in the sea lice vaccine, a further three years' work is predicted in the pre-competitive stage before they are likely to get involved (A. Munro pers.comm.).

16.8.10 Clearly an effective vaccine will provide a major breakthrough in the battle against sea lice, to the benefit of both the industry and the marine environment. However, it is considered to be up to 10 years away from fruition.

# 17 ANTIFOULANTS

17.1 In addition to disease and parasite treatments, an important source of toxic chemical discharges by the industry is from antifoulants used on the cage structures and nets to prevent the growth of marine plants and animals. Since the highly toxic and damaging antifoulant tributyltin (TBT) was banned from use on fish farm nets and cages in 1987, a range of other antifoulants have been used, including copper-based products. Also, physical drying of the nets has been widely used as a solution to fouling. However, SEPA has now expressed concern that, with the introduction of increasingly large cages, the industry is turning away from the practice of net drying and use of copper-based antifoulants is again increasing (SEPA 1996).

17.2 Antifoulants present both acute and chronic pollution problems. Washing of treated nets onshore has been found to result in unacceptably high concentrations of copper and zinc in the spent washings (SEPA 1997). SEPA will not now grant discharge consent for net washers which will be used for nets treated with antifoulants. However, there is also concern about the constant leaching of these elements from the nets while they are in use.

17.3 Copper is acutely toxic to aquatic organisms and has chronic toxic effects even at low concentrations. Copper is also bioaccumulated in aquatic plants and invertebrates, although not in the flesh of fish, and concentrations of the element tend to increase as it passes through the food chain (SFT 1993). However, copper also forms complexes very quickly and it is not clear to what extent this reduces its toxicity.

17.4 The level of antifoulant use on salmon cages is recorded in Norway and has caused considerable concern. There, the use of copper-based antifoulants almost trebled between 1985 and 1990, reaching about 120 tonnes per year, exceeding the inputs from antifouling paints on ships (SFT 1993). An environmental objective was set to reduce the use of copper in fish farm antifoulants by 80% from 1991 levels by 1995, with a long-term objective to eliminate copper releases from this source (SFT 1993). However, these objectives are not yet being met as the use of copper has continued to rise (SFT 1995).

17.5 The use of antifoulants is not, at present, regulated by fish farm discharge consents in Scotland and no figures are available for inputs. SEPA is currently looking into a long-term monitoring programme for copper from antifoulants and is considering bringing this application under the control of discharge consent.

# 18 CONTROL OF MEDICINE AND CHEMICAL USE

## 18.1 Veterinary medicines regulations

18.1.1 Most of the chemical treatments detailed in the previous section are legally classified as veterinary medicines in the context of their use in salmon farming and, as such are governed by the Medicines Act 1968 and its associated regulations. The regulation of veterinary medicines is overseen by the Veterinary Medicines Directorate (VMD) of the Ministry of Agriculture, Fisheries and Food, with advice from the Veterinary Products Committee (VPC). Professor Randolf Richards of the Institute of Aquaculture (IoA) at Stirling University, whose work on new treatments for sea lice is partly funded by the fish farming industry (IoA Annual Report 1994-1995), is one of 20 members of the VPC.

18.1.2 Very broadly, the legislation requires that any veterinary medicinal product has a Marketing Authorisation (MA) for the specific species it is to be used on and the route by which it is to be administered. Products are assessed by the VPC in terms of their safety, quality and efficacy, which is deemed to include their environmental safety. The MA specifies various conditions of use and categorises the product in terms of its availability, for instance whether it is obtainable only on prescription or on general sale.

18.1.3 Most products go through field trials before they are granted an MA and require an Animal Test Certificate (ATC) for this. A guidance note (AMELIA 11) has been produced by the VMD on ecotoxicity testing of medicines intended for use in fish farming (VMD 1996). This gives advice on the preparation of ecotoxicity dossiers required to support applications for MAs and ATCs for fish medicines.

18.1.4 However, the Medicines Act also allows vets to prescribe any product, whether authorised or not, if it is specially prepared for animals under their care. This clause, which is now controlled by the Medicines (Restrictions on the Administration of Veterinary Medicinal Products) Regulations 1994, is being applied in the case of ivermectin through the process known as the "cascade" (see 16.3.12 above). In such applications, the product does not have to go through the VMD's assessment process for either an MA or an ATC.

18.1.5 Many of the treatments used in fish farming, particularly for sea lice control, are themselves, or contain active ingredients that are, classified as pesticides in other applications. The definition in the law is that a substance used to treat animals directly (whether topically or internally) is classified as a medicine. As pesticides, however, they are covered by different legislation: the Food and Environment Protection Act 1985 (FEPA) and the Control of Pesticides Regulations 1986. FEPA specifies a view to "safeguard the environment" and to "make information about pesticides available to the public". Thus all data on approved pesticides (excluding specifically sensitive details regarding sites and formulations) are publicly accessible on the condition that it is not used to progress another product. Application of the Medicines Act, by contrast, is bound totally by commercial confidentiality and it is entirely up to the manufacturer to decide what, if any, data is disclosed. The pharmaceutical companies defend this right on the grounds of protection against competitors. However, the Pesticides Safety Directorate reports no abuse of product data and no complaints from companies of unfair advantage as a result of this system.

### Recommendations

**18.1.6 Given that the application of many veterinary medicines in salmon farming has no lesser implications for public and environmental health than pesticides, the Scottish Office should work with MAFF and the DoE to secure amendment of the Medicines Act and its regulations to bring them into line with FEPA over environmental protection and access to information.**

**18.1.7 In particular, the regulation of "cross-species" use of veterinary products when applied in a different medium from that for which they were authorised needs to be substantially reviewed by MAFF.**

## 18.2 Post-authorisation monitoring of sea lice treatments

18.2.1 The VMD has recognised that sea lice treatments possibly have the greatest potential for environmental damage of all veterinary medicinal products as they are biocides that are placed directly into the environment. It also recognises the limits on data provided prior to authorisation means effects may occur that were not predicted pre-authorisation. In addition, SEPA's site monitoring requirements for fish farms are designed largely to detect the effects of waste solids and nutrients rather than chemical inputs. The VMD has, therefore, initiated a project to investigate the environmental impact of sea lice treatments through the monitoring of biological communities. This project is currently in the early design stage and is being developed under a contract to the Department of the Environment. The project itself is envisaged to take five years but it has yet to secure funding.

18.2.2 Fairly major concerns have been raised over the purpose and practicality of the project as proposed. Most fundamentally, authorising the commercial use of a product and then monitoring its effects afterwards represents a reversal of the precautionary principle. In effect, such monitoring could encourage the authorisation of products without adequate prior environmental assessment. Furthermore, given the pressures on commercial salmon farm operations and the range of chemical discharges made from any site, it is questionable whether it would be possible to isolate the effects of any specific input. Concern has also been raised about the inadequacy of existing knowledge about the dynamics of coastal and marine communities to be able to interpret meaningfully any results obtained.

### Recommendation

**18.2.3 Chemical and medicinal treatments that are being considered for authorisation by the VMD and SEPA should be subject to ecological assessment in the field only in the context of limited authorisation to non-commercial establishments, where inputs can be controlled. This research should be overseen by SEPA and funded, but without influence, by the applicant company.**

## 18.3 Consent to discharge

18.3.1 The discharge of medicines and chemicals (and other trade effluents) by the salmon farming industry is controlled by SEPA. This function is governed by the Control of Pollution Act 1974, as amended by the Water Act 1989, under which all such discharges require consent. The general application of discharge consents is considered in section 14.

18.3.2 For most chemical treatments, SEPA's decision on discharge consent is informed partly by the VMD's assessment and authorisation of the chemical. The responsibility of SEPA lies in considering the impact of the chemical discharge in the wider context of its application and with regard to the particular conditions of the local site. However, in the case of ivermectin, SEPA's evaluation of the chemical represented the sole assessment of its safety in the fish farming context.

18.3.3 The Government guidance note on SEPA and Sustainable Development (Scottish Office 1996) states that in assessing likely costs and benefits of a case SEPA may consider the precautionary principle. It also notes that reconciliation of the needs of the environment and those of development can be furthered by the adoption of improved technologies and management techniques as an integral part of industrial and commercial investment. Towards this end, SEPA is instructed "to establish clear and consistent policy parameters so that regulated organisations can plan for the future".

### Recommendations

**18.3.4 The industry should place more emphasis on the prevention of sea lice and disease problems through improved husbandry practices, particularly with regard to stocking densities, and site management, such as fallowing. SEPA should enforce this approach through the introduction of stringent requirements.**

**18.3.5 In preference to chemical therapeutants, the industry should adopt, and SEPA should promote, the use of biological control methods, such as cleaner-fish, and the development of other non-toxic means of sea lice removal.**

**18.3.6 SEPA should adopt a clear presumption against the continued reliance on and further development of toxic therapeutant and chemical use consistent with its guidance on sustainable development.**

# INTERACTIONS WITH PREDATORY WILDLIFE

## Summary

Predation by seals and birds can be a major problem at salmon farms and the measures taken to protect fish stocks can be highly detrimental to the wildlife. Not enough emphasis has been placed on siting salmon farms away from important wildlife areas to try to avoid the problem arising.

Shooting of both birds and seals has been a common response to predation. A recent change to the Wildlife and Countryside Act tightened up the protection of birds so that fish farmers can no longer shoot birds to protect fisheries without a licence. However, the conditions under which licences are issued still needs to be clarified. Seals can still be shot for the protection of fisheries under the Conservation of Seals Act although it is still not clear whether this defence clause extends to fish farms.

Acoustic deterrent devices have become the main form of protection against seal predation as a result of the development of new high powered models such as the Seal Scrammer. The noise output is designed to cause pain or discomfort to seals approaching or attacking salmon cages. However, there is growing evidence that they are likely also to impact on other marine mammals such as harbour porpoises which tend to occur in the same areas as salmon farms. Studies suggest the distribution of porpoises may be affected at distances up to 3km from the devices, which could cause significant reduction in the habitat available to them. However, there is no assessment or regulation of the use of acoustic devices in the UK.

SWCL proposes that:

- Full account should be taken of the distribution of wildlife and the risk of predation in selecting the location for salmon farms and in determining applications for new sites;
- Shooting of seals should only occur under licence and such licences for seals and birds should be contingent on preventative measures having proved unsuccessful;
- The use of acoustic deterrent devices should be subject to environmental impact assessment and licensing.

## 19 SITING

19.1 It is well recognised that salmon farms attract predatory wildlife, most commonly seals (grey and common) and birds (cormorants, shags, herons and gulls), that predate directly on the farmed fish or on the wild fish which feed around the cages, or scavenge on dead fish at sites or the fish feed left on cages (Ross 1988; Carss 1994; Furness 1996). It is equally well documented that preventing predation can be extremely difficult and failure can result in substantial losses to the farm through dead, damaged and stressed fish. Equally, the measures taken to protect fish stocks can be detrimental to the wildlife concerned, whether through destruction (shooting or entanglement in nets), disturbance, or displacement, raising both conservation and welfare concerns.

19.2 The proximity of the farm site to concentrations of predatory wildlife species is likely to have a significant influence on the level of damage suffered. The siting of a salmon farm, avoiding predatory wildlife, should therefore be a central component of the anti-predation strategy.

19.3 Important areas for wildlife, such as haul-out sites, breeding colonies or feeding grounds, may be identified by conservation designations such as Sites of Special Scientific Interest (SSSIs), Special Protection Areas (SPAs) or Special Areas for Conservation (SACs) that should be recognised in planning considerations. However, not all concentrations of relevant wildlife species are covered by such protected areas. It is, therefore, vital that the distribution and movements of predatory wildlife are taken fully into account in decisions on the siting of salmon farms.

### Recommendation

**19.4 The planning control process should take full account of the distribution of wildlife and the risk of predation-related problems, through consultation with SNH, in determining applications for new salmon farm sites.**

# 20 SHOOTING

## 20.1 Birds

20.1.1 Since 1991, the major development affecting birds, as predators on marine salmon farms, has been the amendment of the Wildlife and Countryside Act 1981, to bring it into line with the requirements of the EU Birds Directive. This amendment came into force in November 1995, tightening up the provisions of the existing defence clause that allowed fish farmers to shoot birds for the purposes of protecting fisheries. The new regulation requires that, if a fish farmer can anticipate that it will be necessary to shoot birds to protect a fishery, then he or she must apply for a licence. In addition, all shooting of birds, whether licensed or not, has to be reported to SOAEFD as soon as practicable after it has taken place.

20.1.2 SOAEFD wrote to all fish farmers and shellfish farmers in February 1996 notifiying them of the changes and advising that only where it is absolutely clear there is an urgent need to shoot and such a situation could not have been anticipated is it possible for action to be taken without a licence – and in that event the fish farmer would still be required to report the shooting to the department.

20.1.3 Before a licence is issued, SOAEFD must first be satisfied that non-lethal alternatives to killing have been tried and "serious damage" to the fishery is being caused. To date there does not appear to have been any attempt by SOAEFD to define "serious damage" as is legally required.

20.1.4 Prior to the change in legislation there were very few applications for licences to be issued to fish farmers for shooting birds as they believed they could rely on the defence clause (SOAEFD pers.comm.). SOAEFD does not record data on licences issued to, and birds shot by fish farmers separately from other appplicants such as fishery managers and sport-fishing interests. However, SOAEFD reports that applications for licences generally have increased since the law changed. The total number of bird licences issued in 1996 was 46, compared to 22 in 1995 and 35 in 1994 (SOAEFD pers. comm.). However, the number of birds reported as shot varies between years and does not appear to have increased dramatically. These figures may reflect the effectiveness of the reporting system as much as the reality of shooting. SOAEFD has no records of any birds shot without the authorisation of a licence.

20.1.5 SOAEFD states that since the change in the Wildlife and Countryside Act all new sites applying for a licence to shoot birds are visited to ascertain the need and what anti-predation measures are in place. However, there does not appear to be a clear agreed policy over consultation, especially with respect to SNH as the statutory conservation agency. The law stipulates only that the Secretary of State shall from time to time consult with SNH. SOAEFD states that SNH is consulted if the shooting is to take place in the vicinity of an SSSI, an SPA or a proposed SAC, or if a site visit is being arranged.

20.1.6 There also appears to be a problem over the provision of information to support applications. SNH frequently receives notice of applications from SOAEFD with no indication of the nature of the installation or the justification of the case as applicants' details are treated as confidential by SOAEFD. In addition, there is no agreed definition, or even general guidance, as to what constitutes "serious damage" or the criteria used to justify shooting. Given these shortcomings, licensing practice appears to operate on a somewhat ad hoc basis.

20.1.7 The SSGA considers that all salmon farms now use top nets on their cages so predation by birds is no longer an issue (W. Crowe pers.comm.). However, predation by diving birds such as cormorants and shags usually occurs underwater, from the outside of cages which would not be protected by such nets. In addition, what may be regarded as a more significant problem is the mess made by gulls scavenging on spilled feed on the cages. Such birds are shot at by operatives in order to scare them. Clearly, improved handling of feed would provide a better solution to this problem.

### Recommendations

20.1.8 **Scottish Office policy on the assessment and issuing of licences for shooting birds needs to be publicly stated. A definition of what constitutes "serious damage" should be set out using clearly specified criteria.**

20.1.9 **Licensing policy should continue to be based on the precautionary principle, requiring alternative measures to killing to be taken before licensing is considered.**

20.1.10 **Clear policy must be agreed between SOAEFD and SNH over consultation procedures and the provision of information on applications for licences to shoot birds.**

## 20.2 Seals

20.2.1 No shooting of seals has been authorised at fish farm sites in the years from 1991 to 1996. Equally, SOAEFD has no records of any seals being shot at fish farms over this period. SOAEFD merely states that illegal shooting is a matter for the police and the Procurator Fiscal (SOAEFD pers.comm.).

20.2.2 However, it is clear that not all shooting of seals that occurs without the authorisation of a licence is necessarily illegal. The defence clause of the Conservation of Seals Act 1970 is available to fishermen, allowing seals to be shot in order to prevent damage to "fisheries". The definition of what level of damage constitutes a justification of defensive shooting is unclear, as are the conditions under which it can occur. In the past, the Scottish Office has offered guidance that defensive shooting should only occur "in the vicinity of" nets or cages, although this condition is reported to have been widely flouted. However, after 27 years of the Conservation of Seals Act being in place, it is apparently still not clear whether the defence clause applies to fish farms. The Scottish Office reports it is seeking legal advice on this matter (SOAEFD pers.comm.).

20.2.3 The Scottish Office reports that the police are improving their implementation of shooting restrictions through the initiative of wildlife liaison officers. While enforcement of the law on wildlife shooting has generally been regarded as inadequate, conservation bodies are encouraged by the current increase in the number of wildlife officers on the ground (J. Ralston SNH pers.comm.).

### Recommendations

20.2.4 **Legislation on the shooting of seals needs to be amended so that a licence must be obtained before any attempt is made to kill or take a seal.**

20.2.5 **In order to obtain such a licence the applicant should be able to demonstrate the severity of the predation problem and that properly deployed non-lethal control methods have proved unsuccessful.**

20.2.6 **It should be a condition of licensing that all shooting of seals should be reported to the licensing authority.**

### 20.3 Otters

12.3.1 Although otters are not generally considered to be a major problem at marine salmon farms, permission has been requested from the Scottish Office to trap and remove animals from sites. Licences are only issued for the relocation of otters. In 1994 one licence was granted, but because the trapping exercise was unsuccessful, no otters were moved in this case (SOAEFD pers.comm.).

## 21 SCARERS

### 21.1 Development of acoustic deterrent devices (ADDs)

21.1.1 In the late 1980s, the main forms of protection of salmon farms against seal predation were anti-predator nets and shooting. Seal scarers, or acoustic deterrent devices, were used at some sites but with limited and usually short-lived success, largely because the seals habituate to the noise. In fact, in some applications the devices have been found to take on a "dinner-bell" effect, attracting the animals to a ready source of food (Reeves et al 1996). The response of manufacturers has been to produce new generations of devices with increased power and frequency range, targeting the frequencies to which seals are most sensitive. The industry now seems to consider these devices reliable and effective. However, there is increasing concern about their potential impacts on both the target seals and non-target species, particularly cetaceans such as the harbour porpoise which tend to inhabit the areas in which ADDs are used. The effects of ADDs on marine mammals have been extensively reviewed by V. Taylor and D. Johnston (in prep.), which is the source of much of the information in this section.

21.1.2 The ADD used most widely in Scotland seems to be the Seal Scrammer produced by Ferranti-Thomson Sonar Systems UK Ltd. Mark 2 of this device produces a noise of 196 decibels (dB) re 1μPa at 1m at 25kHz. It has a pulse lasting for about 20 seconds for up to six times per hour. The Mark 2 4X device produces a noise of 200dB re 1μPa at 1m at 25kHz, with the signal ranging from 7 to 35kHz. The pulse lasts for about 20 seconds for up to 20 times per hour (Ferranti-Thomson sales literature). Other acoustic devices are being produced for the salmon farming industry in North America (by Airmar Technology and PRA Systems) with sources of up to 205dB re 1μPa at 1m ranging from 10kHz to 38.4kHz.

21.1.3 These high energy ADDs, sited on or near salmon farms, cause approaching or predating marine mammals to experience pain or discomfort (Olesiuk et al 1995; Reeves et al 1996). They come with a range of operational features. These include sensors that trigger the device when a seal makes contact with the net and variable frequency and timing options all designed to minimise habituation to the sound. Manufacturers report these very high-powered ADDs have remained effective for at least two to three years with no signs of habituation or declining effectiveness (Reeves 1996). However, several, including Ferranti-Thomson Sonar Systems UK Ltd, have recently increased the technical specifications of their devices (V. Taylor UFAW pers.comm.) and other more powerful models are currently being developed (Olesiuk et al 1995).

## 21.2 Impacts of ADDs

21.2.1 No research has been conducted in the UK into the effects of ADDs on either seals or non-target species. The Sea Mammal Research Unit has a Seal Scrammer on loan from Ferranti-Thomson and plans to conduct field trials to monitor the reactions of seals to the device in 1997. This work may also include monitoring of harbour porpoises.

21.2.2 However, some worrying results have emerged from research in the US and Canada. The propagation of sound produced by a device will vary according to a range of local factors, including water depth, seabed profile, temperature and salinity. The data produced in experimental trials using two devices (Airmar and PRA) suggest their signals may be broadcast over considerable distances, in the order of tens of kilometres, before dissipating to background levels (Olesiuk et al 1995).

21.2.3 The ability to distinguish sounds and locate their direction is important for all marine mammals and is used in communication, predator detection, prey location and, in the small cetaceans (and other toothed whales), for echo location. Therefore they have highly specialised inner ears, adapted for the type of sound and the circumstances they are most likely to encounter. The true seals (*Phocids*), which include those found in the UK, can detect very high frequencies of up to 180kHz but tend to be most sensitive to frequencies between 1 to 50 kHz. However, the seals' hearing sensitivity in this range is not as high as the small cetaceans, most of which have a very wide hearing range from 75Hz to 150kHz with the greatest sensitivity around 20kHz (Richardson et al 1995). The ADDs are, therefore, typically transmitting at frequencies to which seals and small cetaceans are most sensitive.

21.2.4 Human induced sounds have been found to have deleterious effects on marine mammals ranging from disturbance of behaviour and displacement from an area, to interference with normal sound detection and, in extreme cases, temporary or permanent loss of hearing sensitivity (Evans 1996, Richardson et al 1995). The impact of the high intensity and frequency of sound produced by new ADDs is still relatively unknown. However, various estimates have been made as to what sounds are likely to cause effects. For harbour porpoises, Okesiuk et al (1995) estimate that noise of 90 dB above the absolute hearing threshold of 50dB would cause discomfort, 120 dB above would cause pain and that 160dB would cause hearing impairment. Evans and Nice (1996) consider a sound level of 150-170dB at 10-100kHz would be excessively loud for the bottlenose dolphin. Cetaceans are also predicted to show a behavioural response at about 30dB above their hearing threshold (Richardson et al 1995).

21.2.5 It is considered unlikely that many marine mammals would remain for long in areas where received levels of continuous noise are 140dB or more at frequencies to which they are most sensitive (Richardson et al 1995). However, it is not clear that animals would necessarily leave before hearing impairment had occurred, for instance humpback whales have been found with ear damage in areas characterised by industrial noise (Evans & Nice 1996).

21.2.6 The effects of ADDs on harbour porpoises at various distances from the source have been estimated on the basis of the noise characteristics of the Airmar and PRA devices measured in field trials (Haller & Lemon 1994, Olesiuk et al 1995). As a rough approximation, applying known human thresholds for hearing impairment, Olesiuk et al estimate that ADDs are capable of inflicting immediate hearing impairment at a range of 16cm, pain at a range of 20m and discomfort at a range of 475m. The predicted zone of discomfort corresponds roughly with the observed 400m radius from which porpoises were completely excluded when the ADD was activated in field trials.

21.2.7 The actual effect of ADD operation on the distribution of harbour porpoises has been recorded in Retreat Passage, British Columbia (Olesiuk et al 1995). This study recorded a dramatic and almost immediate reduction in the number of porpoises seen when the device was activated. Sighting dropped to just 9.7% of expected number within 2500-3000m, 3% within 600-2499m, 0.8% within 400-599m and none were recorded within 400m. Incidental sightings of common seals during the study indicated a much less pronounced response than that of the porpoises. The authors concluded these powerful devices had far-reaching implications for non-target species such as cetaceans and could significantly reduce habitat availability.

21.2.8 The effects of ADDs will depend to some extent on the way in which they are operated, for instance, whether they are emitting constantly, intermittently or in response to predator presence, and how long they are activated for. The greatest risk of immediate physical damage is likely to occur when a device is switched on at full power when the animal is close by or when it is triggered automatically by a net sensor. On the other hand, reactive models that only transmit when triggered are less likely to cause general disturbance and displacement of more distant animals than those transmitting constantly. A potentially less damaging mode of operation would be a reactive device that starts emitting at a lower sound level and gradually builds up to full power, thus giving animals the opportunity to move out of the area (Richardson et al 1995).

21.2.9 In addition to the direct impact on marine mammals, ADDs have the potential to affect species indirectly, and to affect the commercial interests of fishermen directly, by impacting on fish distribution. The specific effects of ADDs on wild fish have not been investigated. However, studies of seismic testing using underwater air guns have shown physiological effects, including stunning from 192dB (Evans & Nice 1996). A further study showed cod and haddock catch levels were affected at distances of up to 18 nautical miles from the noise source, with catch reductions of up to 70% recorded (Engas et al 1993).

## 21.3 Use and regulation of ADDs

21.3.1 Acoustic seal scarers are now reported to be the main form of anti-predator protection in the Scottish salmon farming industry, used by an estimated 75% of farms (W. Crowe pers.comm.). Ferranti-Thomson's own sales literature of 1995 states that over 100 seal scrammers are in use in Scotland. Although some farms still use anti-predator nets, confidence in seal scrammers means many no longer bother with net protection.

21.3.2 The SSGA produced a code of practice on predator control in 1990 in conjunction with the then Nature Conservancy Council and SWCL member bodies (SSGA 1990). This required SSGA members to record and report all predation events and the prevention measures taken at the site. However, the SSGA no longer requires this feedback from companies and is therefore not in a position to provide information on the extent of predation, the effectiveness of control techniques in use, or their potential wider impacts.

21.3.3 The Scottish Office states that as ADDs are non-lethal, do not trap or constrain the animals in any way and have never been shown to cause any lasting detrimental effects, they are viewed as an acceptable method of control (S. Clarkson SOAEFD correspondence to V. Taylor). There are no plans to regulate their use.

21.3.4 However, there is growing evidence that output from the new forms of ADD represents an acute and widespread form of noise pollution in Scottish waters. It is also occurring in areas of particular importance both to the target seals and to vulnerable cetacean species such as the harbour porpoise. Despite this, no monitoring has occurred in the UK either of the extent of ADD operation, or their effects. Furthermore, despite the UK's international commitment to reduce the acoustic disturbance of small cetaceans under the Agreement on the Conservation of Small Cetaceans of the Baltic and North Seas (ASCOBANS) there is currently no mechanism in place for regulating the use of acoustic deterrent devices.

## 21.4 Recommendations

**21.4.1 The Scottish Office should undertake a full environmental impact assessment of the use of acoustic deterrent devices by the salmon farming industry.**

**21.4.2 The use of high output ADDs should be subject to licensing by the Scottish Office in consultation with SNH and SEPA. ADDs should only be permitted where anti-predator nets are shown to have been properly and persistently deployed and to have failed. ADDs should supplement rather than replace physical protection measures.**

**21.4.3 Licensing of ADDs should also be subject to a case by case assessment of the conditions of the site, in terms of noise attenuation, and the likely impact on target and non-target species, especially in areas important for feeding, breeding and movement.**

**21.4.4 An environmental appraisal should be required of each new ADD model before it comes into use and measures stipulated to minimise potential adverse effects, such as a milder warning noise before the device builds up to full output.**

# THREATS TO WILD STOCKS

## Summary

There is increasing concern about the potential impact of salmon farming on the status of wild salmonid stocks. The considerable losses of farmed fish, that occur both through poor containment and handling and as a result of accidents, are now being reflected as alarmingly high percentages of the salmon recorded in the wild. These escaped farmed salmon not only compete with wild stocks for food and resources but also breed successfully with wild salmon and, indeed, hybridise with wild brown trout. The use of non-local stocks in farms and selective breeding for favourable traits produce farmed fish that are genetically different from wild fish and inter-breeding could result in changes in the genetic make-up of wild stocks, potentially affecting their capacity to survive.

The recent development of genetically modified salmon that grow many times faster than ordinary fish has massively heightened concerns about the risk of escapes and their impact in the wild. An experimental project has produced these transgenic salmon in Scotland in contained land-based conditions. This project is no longer expected to lead to commercial production and the Scottish industry does not currently condone the use of genetically modified fish. However, the case has revealed serious weaknesses in the legislation that call into question its capacity to control the potential risks associated with production of genetically modified fish or their export.

Another major concern surrounds the potential for farmed salmon to transmit disease to wild stocks. In particular, sea lice have been implicated in the recent catastrophic decline in sea trout populations in north west Scotland. While conclusive proof of the cause has not been established, and several factors may be involved, there is widespread agreement that an increase in sea lice is the likely cause of much of the trout mortality. The sea lice infestations are also closely associated with the distribution of salmon farms, implicating them as the source.

SWCL proposes that:

- Escapes of farmed salmon should be centrally recorded, measures for containment monitored and contingency plans for large escapes required for each site;
- The siting of both freshwater and marine salmon farm sites should be planned to avoid any impact on wild stocks;
- The production of genetically modified fish should be prohibited in the UK;
- Legislation should be reviewed with regard to the environmental impact of "contained" GMOs and their export from the UK;
- Precautionary measures should be introduced to minimise the impact of sea lice on sea trout, using non-chemical methods of sea lice control and good husbandry.

# 22 SALMON FARM ESCAPES

## 22.1 Prevalence of farmed salmon in the wild

22.1.1 The escape of farmed salmon into the wild is considered inevitable and losses occur from most sites every year. Small numbers of fish escape intermittently and sometimes frequently as a result of careless handling of nets or equipment failure (Webb 1994). However, major losses of many thousands of fish also occur, usually as a result of storm damage or the loss of cage moorings, or through seal predation or accidents. Examples of serious losses caused by storm damage include one case of 184,000 salmon lost in northern Scotland, and two cases involving 700,000 and 1,423,000 salmon lost in Norway. In Orkney the loss of 100,000 smolts was reported when a transport ship ran aground (Webb; Gausen & Moen; Gausen; Mills all cited in NASCO 1993). In addition, surplus farm stock have been released deliberately or sold for stock enhancement (Maitland 1987). However, the salmon farming industry reports that surplus stock are no longer released (NASCO 1994a).

22.1.2 It is estimated that 2 million fish escaped from salmon farms in Norway in 1991 (Bergan et al 1991). Technical inspection of farms was reported to have contributed to a reduction in losses to 500,000 in 1992 (NASCO 1994a), although this subsequently rose to 646,500 in 1995 (P. Hutchinson NASCO pers.comm.). These figures represent the losses reported to the authorities but the actual number of escapes is not known.

22.1.3 There is now considerable evidence from a number of countries of substantial numbers of farmed salmon occurring in the wild (NASCO 1993). Since there is no absolute method to positively identify all fish as either wild or farmed, estimates of the proportion of escaped farmed salmon will tend to be less than the true levels (Webb 1994). Sampling in the Faroese fishing zone has shown 25-48% of the salmon caught at sea were farmed fish. In Norway, farmed salmon were found in 70% of the rivers sampled in 1988 and comprised up to 77% of the salmon sampled (Gausen and Moen 1991). More recent studies in Norway indicate that up to 90% of the fish in some rivers may be of farmed origin (NASCO 1993) and 42% of the catch in coastal salmon fisheries were farmed salmon in 1995 (P. Hutchinson pers.comm.).

22.1.4 In Scotland commercial catches of farmed salmon at coastal netting stations have been monitored by scientists from the Freshwater Fisheries Laboratory since 1990, with a concentrated research effort at Gairloch. Here, escaped farmed salmon averaged 22% of the catch over the netting season, although in June of 1993 levels rose to about 66% of the total monthly catch. This compared with a range of 1-20% at other west and north west regions and from 1-6% on the east coast (Webb 1994). Sampling of angling catches on the River Lochy was conducted between 1988 and 1990. The results showed great variability between years, with farmed salmon making up 18.5% of the total catch in 1988 and 61.5% in 1990, but with no farmed fish recorded in 1989 (SOAFD 1991). In the River Polla, 54% of the angling catch were estimated to be of farmed origin in the season after a large escape in the nearby loch (Webb et al 1991).

22.1.5 There is no routine monitoring or any statutory requirement to report the loss of fish from salmon farms in Scotland. The Scottish Office states it has a mechanism for authorising measures to retrieve fish after a large escape (D. Dunkley SOAEFD pers.comm.) although the industry appears not to be aware of this (W. Crowe pers.comm.). Apart from specific scientific studies, the only measure of the level of escapes is generated from reports of farmed fish in the statutory returns from salmon fisheries. In 1995 a total of 485 farmed fish was reported, representing 0.3% of the total catch (SOAEFD 1996). It should be emphasised this catch level is a minimum as not all fish of farmed origin are correctly identified by fishermen. Those that escape before smoltification are particularly difficult to distinguish from wild fish (D. Dunkley pers.comm.). The 1995 recorded catches of farmed salmon were a substantial reduction on 1994 levels and possibly indicate that improvements have been made in containment by the industry.

## 22.2 Spawning of farmed salmon in the wild

22.2.1 Detailed research on the River Polla revealed that only 0.5% of the 184,000 fish that had escaped from a nearby farm returned to the River Polla and there was no evidence of substantial returns to neighbouring rivers, suggesting that survival at sea was low after the escape (Webb et al 1993). The farmed salmon that entered the river did so during the summer but tended to spawn later than the wild fish, in November. The farmed females had a more limited distribution than either farmed males or the wild females, spawning mainly in the middle or lower reaches of the river (Webb 1994), although this was subsequently attributed to the possible influence of a hatchery near the mouth of the river (Webb et al cited in NASCO 1993). Webb et al (1991) also observed farmed fish of both sexes spawn freely with wild fish.

22.2.2 The spawning behaviour of farmed females on the Polla was studied by detection of the artificial flesh pigment canthaxanthin which was fed to the fish in captivity. This pigment is passed on to the ova of farmed fish and can be simply differentiated by laboratory test from the natural pigment, astaxanthin, in ova from wild salmon (Webb 1994). This technique was then applied to alevins and fry to study the extent of spawning by farmed females in western and northern Scottish rivers. Of the 16 rivers studied, fry from escaped farmed females were found in 14, at an average 5% but ranging up to 18% of the total. The highest frequencies of fry containing canthaxanthin were found in the most intensive salmon farming area. These results would have underestimated the true level of spawning by escaped fish as only 65% of escaped farmed salmon were found to contain canthaxanthin and this technique gives no indication of spawning input by escaped males (Webb 1994).

## 22.3 Hybridisation with brown trout

22.3.1 Natural hybrids between Atlantic salmon and brown (or sea) trout have been identified widely where the ranges of the two species overlap but usually at low frequencies (Youngson et al 1993). In a study of western and northern Scottish rivers hybrids were found in seven of the 16 rivers examined. The offspring of female salmon of farmed origin were again identified by the presence of canthaxanthin, which was identified in 4% of the pure salmon fry but in 35% of the salmon/trout hybrids (Youngson et al 1993). The results indicate that escaped farmed female salmon are about 10 times more likely to hybridise with trout than are wild female salmon (Webb 1994). This is thought to be a result of impaired sexual behaviour in farmed salmon arising either from the cage environment or from selective breeding. The continued distinctness of salmon and sea trout, despite widespread natural hybridisation, suggests the hybrids have reduced fitness. However, the effects of the increased rate of hybridisation with escaped salmon are still to be assessed (Youngson et al 1993).

## 22.4 Environmental impact of escapes

22.4.1 Considerable concern has been expressed over the possible adverse effects of escaped farmed salmon on wild salmon stocks. The salmon farming areas in Scotland coincide with important salmon fisheries with most cage sites located within 20 km of the nearest salmon river (Webb 1994). Potential impacts may arise on two levels: direct ecological effects and genetic effects.

22.4.2 Ecological impacts are likely to arise mainly from increased competition over resources. It is frequently argued that the selective breeding of farmed salmon for traits suitable for culture, such as late maturation and docility, render them less fit to survive in the wild. Indeed a number of studies indicate that survival in the wild of farm reared salmon is lower than that of wild fish (various cited in NASCO 1993). However, the sheer numbers of farm escapes, which in many instances exceed wild populations in a river, suggests that during their lifetime escaped salmon can pose a significant threat. Apart from competition for food resources, negative consequences of the spawning of farmed fish in wild salmon rivers are predicted as a result of competition for spawning habitats among adults and competition for freshwater habitat and food among resultant juveniles (Webb 1994). For instance, farmed females have been observed to spawn on grounds already used by wild females (Webb 1991).

22.4.3 There are more serious concerns about the genetic effects of widespread spawning by escaped farm salmon. These include the potential homogenisation of the genetic base of wild salmon populations, loss or dilution of adaptive gene complexes within wild populations and increased hybridisation with wild brown trout. It is feared these may lead to a reduction in the productivity, diversity, and therefore the resilience, of the indigenous populations (Webb 1994).

22.4.4 Research on the genetics of wild salmon populations suggests that each river which supports Atlantic salmon may be inhabited by one or more genetically distinct forms (NASCO 1993). A number of further studies have shown different genetic make-ups affect various attributes of the fish, from physical shape to resistance to infection. There is also some evidence that the homing ability of salmon may be under genetic control (Riddell et al 1980; Winter et al 1980; Barns 1976 cited in NASCO 1993). These findings suggest the genetic differences between populations are of adaptive significance.

22.4.5 Farmed fish are likely to differ genetically from wild stocks for a number of reasons. The source of the farmed stocks may not have been local, "founder effects" may result from small original broodstock and random genetic drift may occur within the broodstock. In addition fish farmers may actively modify the genetic make-up of their stock through selective breeding (Youngson et al 1991).

22.4.6 Concern about the possible adverse genetic effects of farmed Atlantic salmon on wild stocks is based largely on evidence from other species such as steelhead (*Salmo gairdneri*) and chum salmon (*Oncorhynchus keta*). Researchers demonstrated that interbreeding of farm reared fish with wild fish may lead to a reduction in smolt output and survival and concluded that frequent inputs of hatchery fish would lead to changes in the genetic characteristics of the wild stocks (NASCO 1993). A review of the results observed in wild fish populations found a range from no effect to complete genetic introgression or displacement, and where genetic effects on performance traits occur they always appear to be negative in comparison with the unaffected population (Hindar et al 1991). The authors warned that without a necessary reservoir of genetic variation, the species becomes vulnerable to environmental changes and to disease from which it might not recover, with consequences both for the wild stocks and the aquaculture industry.

22.4.7 Current research in Scotland includes a jointly-funded EC and Scottish Office study, based on the River Loth, on the effects of introduced non-native fish on the performance of native populations of salmon. This project involves the experimental release of genetically distinguishable fish and has revealed differences in performance in a number of traits, including some that suggest local adaptations (E. Verspoor, SO Marine Lab. pers.comm.). A further EC-funded project is being conducted in Scotland, Norway and Ireland to investigate the ecological and genetic effects of the spawning of escaped farmed salmon on wild salmon and trout populations. Results from these projects are expected to be presented in early 1997 (J. Webb, Atlantic Salmon Trust pers.comm.).

## 22.5 Measures to minimise the impact – containment

22.5.1 The genetic risk to wild Atlantic salmon has led to repeated recommendations for improved containment of farmed fish and the use of sterile salmon that are unable to reproduce if they escape. More recently, moves to protect the genetic integrity of wild stocks have been given added impetus by the production of transgenic fish for aquaculture, that is fish that have been genetically modified to bear genes from other species (NASCO 1993).

22.5.2 The West Highland Sea Trout and Salmon Group (WHSTSG) was set up in 1994, consisting of representatives of salmon fisheries and anglers, the SSGA, Crown Estate and Scottish Office. The Group set itself the remit "to work together with local and other interests to rehabilitate, through co-ordination, co-operation, appropriate resourcing and other means, the sea trout and wild salmon fisheries in the West Highlands of Scotland" (WHSTSG 1995). In its Action Plan, the group identified the minimisation of the interaction of farmed fish with wild fish stocks as a key objective (WHSTSG 1995). In fact the plan recommends little that the fish farming industry would say is not already being done. For instance, it recommends that fish farmers should optimise containment of farmed fish to minimise escapes, with continued emphasis on inspection and maintenance. The plan also recommends that site specific contingency plans be developed to deal with any large scale escape of fish. However, the industry is not implementing this recommendation as it argues that retrieval of escaped salmon would require a change in existing legislation to enable the use of netting techniques that would otherwise be illegal (W. Crowe pers. comm.).

22.5.3 The fact remains that escapes from cage facilities are regarded as inevitable and it is generally accepted that total containment is only feasible in land based tanks with effective security and screening of outflows (NASCO 1993). The WHSTSG Action Plan endorses the stated presumption by the Crown Estate against siting new salmon cages at the mouth of sea trout and salmon rivers to try to minimise the impact of fish that do escape. However, this presumption has not been rigorously applied to date. Moreover, planning consents are being granted to site smolt-rearing cages in the headwaters of salmon rivers, such as a case in Loch Shin in 1996. In Norway, by contrast, it is generally not legal to raise smolts in a lake or river which has wild anadromous salmonids or which supplies salmon or trout rivers (Yngve Svarte, Directorate for Nature Management, correspondence to J. Inglis 5.7.96). The main reasons for these prohibitions are the possible genetic effects on the wild stocks in the event of escapes, the possible transmission of diseases between farmed and wild fish and the chemical and organic pollution of the water bodies.

## 22.6 Measures to minimise the impact – sterilisation

22.6.1 A more effective means of protection against genetic interactions is through the use of sterile farmed fish. The only technique presently available for use on a commercial scale is the production of all-female triploid salmon. These technologies were initially developed to control the maturation of fish for commercial purposes and their use in the UK has been reviewed by Johnstone (1996). All-female stocks of rainbow trout have been used since the early 1980s, using hormone treatment to produce sex-reversed "males". This approach was not taken up by salmon farmers as early maturation is not confined to male salmon. The production of triploid fish provided a potential solution as, by containing three sets of chromosomes instead of two, they are sterile. Triploidy can be induced by pressure shock treatment of fertilised eggs, which can achieve close to 100% triploid rate but human and mechanical error reduce this rate in practice (R. Johnstone pers.comm.).

22.6.2 Although triploid males are functionally sterile, they continue to produce the hormones that lead to the deterioration of the fish associated with maturation. Triploid females, on the other hand, are both functionally and hormonally sterile and therefore offer potential commercial interest. The production of all-female triploid stocks of salmon was available to the industry in the late 1980s, and in 1989 some 7.5% of ova were produced in this state. However, the commercial experience of triploid fish was not good, with problems of poorer growth and greater susceptibility to disease and cataract formation. As a result, no all-female or all-female triploid salmon stocks are being reared in the UK (Johnstone 1996).

22.6.3 The concern about genetic damage to wild salmon has led to the potential of sterile fish being scrutinised again, although it has been noted that these will not solve all the ecological problems associated with escapees, such as competition for resources, and may raise new ones, such as wasted reproductive effort by wild fish (A. Kapuscinski in MacKenzie 1996). A four-year EC-funded project is in progress in Scotland, Norway and Ireland to look at the performance and environmental impact of triploids. The production of triploids may prove to be less efficient than diploid fish. The industry has also expressed concern over the marketing and public perception implications of triploid salmon (NASCO 1994a). However, it has been suggested this may be a measure that the industry will have to embrace if it is to offset the risk to wild fish stocks (Johnstone 1996). It has been proposed that any regulation on the use of sterile fish should be introduced internationally to prevent any one country being put at a competitive disadvantage (NASCO 1994a).

## 22.7 Recommendations

22.7.1 **The incidence, cause and number of escaped farmed salmon from freshwater and marine sites should be centrally recorded by the unified monitoring body established under SEPA.**

22.7.2 **Inspection of farms for the efficacy of containment measures, including handling procedures and the condition of cages and equipment should be conducted on a regular basis by the monitoring body and contingency plans for large escapes should be required from each farm.**

22.7.3 The environmental implications of gender manipulation, triploidy and other relevant technologies should be assessed fully by SEPA before they are considered for introduction on a commercial level. In the interim, the necessary scientific, technical and regulatory requirements for the introduction of a "sterile fish only" policy in cage salmon culture should be investigated by the Scottish Office.

22.7.4 Clear policies should be devised by local planning authorities, under strategic guidance from the Scottish Office and in consultation with SEPA, with regard to the siting of both freshwater and marine salmon farm sites in order to avoid the impact on wild stocks. These policies should be rigorously applied to both new site applications and to existing sites that may present an unacceptable risk.

# 23 GENETICALLY MODIFIED SALMON

## 23.1 The development of transgenic salmon

23.1.1 The development of genetic engineering has enabled the genetic make-up of organisms to be modified in ways that would not occur naturally. Single genes or segments of DNA can be removed and re-inserted in another position in the same organism or into a totally different organism. Where genes are introduced from another organism, the genetically modified organism (GMO) is termed "transgenic" (Paddock 1995).

23.1.2 The production of transgenic animals is expensive and most research effort has concentrated on developing high value products for human medicine rather than food production (NASCO 1996a). However, fish species offer a number of attractions for genetic engineering: they produce many eggs which can be fertilised and remain outside the female's body (Maclean & Penman 1990) with no need for sterile conditions (Fletcher & Davies 1991). As a result, there has been an explosion of research on genetic manipulation of aquaculture species since the early 1980s (Kapuscinski 1990), mainly focused on growth enhancement (Devlin et al 1994). Other areas of investigation include the ability to utilise low cost or vegetarian diets, improved feed conversion and disease resistance (Fletcher & Davies 1991). The production of transgenic fish has been reviewed extensively in a report published by the Department of the Environment (Anon 1994) and the development of transgenic salmon is usefully summarised by NASCO (1996a).

23.1.3 Key commercial developments in transgenic salmon have taken place in Canada, where, in addition to growth enhancement, scientists have been investigating improved cold tolerance (Fletcher & Davies 1991). One research group identified the promoter for an antifreeze protein gene in ocean pout which triggers production of antifreeze when water temperature is low. By introducing a combination of this promoter and a growth hormone gene from chinook salmon into Atlantic salmon, they were able to produce transgenic fish that grow throughout the winter and with a dramatic increase in growth rate, averaging six times that of non-transgenic siblings (Du et al 1992).

## 23.2 Transgenic salmon in Scotland

23.2.1 In 1995, Aqua Bounty Farms, a division of A/F Protein Inc. which operates in Canada and the US, began licensing this transgenic technology to the salmon farming industry, claiming the transgenic fish grow 400 to 600% faster than standard fish. The fish do not become giants as growth stops at the size that triggers sexual maturity, they simply reach this faster (MacKenzie 1996a), producing smolts in three months and reaching market-size in just 12 to 18 months (Aqua Bounty Farms' own literature). Although the technique has not yet been approved for commercial trials in North America, these transgenic Atlantic salmon are now being raised in Scotland and New Zealand (MacKenzie 1996a).

23.2.2 Otter Ferry Salmon, which has a land-based freshwater hatchery and salmon rearing unit on the shore of Loch Fyne, bought the right to this technology, becoming the first experiment of its size with transgenic fish in Europe (MacKenzie 1996a). In late 1995 the Canadian scientists brought the DNA construct used by Du et al (1992) to Scotland to be inserted into 10,000 eggs by micro-injection. The predicted rate of success for the project, in terms of fish expressing the introduced growth hormone, was 1-3%. In fact 60 salmon have been produced that show the trait, with no other abnormalities, and the growth rate of these fish is about five times that of comparable stock (A. Barge, Otter Ferry Salmon pers.comm.).

23.2.3 Although not all the fish were expected to take up the introduced gene construct in all their tissues, the company hoped that most of the fish would be transgenic in their germ line (milt and eggs) and could be used for breeding purposes. Du et al had not established whether their fish with enhanced growth rates would mature or whether the trait is heritable (Otter Ferry 1995). To produce commercially useful results, it is assumed that such a trial would require two more generations of fish, taking a further three years, in order to test the heritability and fidelity of the transgene (A. Munro pers.comm.). The risk assessment for the project states "there is no intention whatsoever that the transgenic fish produced should at any stage enter a production system but should only be retained on an experimental basis for continued assessment" (Otter Ferry 1995).

23.2.4 The transgenic salmon are being reared in tanks in a dedicated building at the Otter Ferry hatchery. The company was obliged to undertake a range of precautions and modifications in order to prevent the escape of any genetically modified organisms, otherwise the project would be regarded as an intentional release to the environment and would require specific consent (P. Logan, HSE, correspondence to Otter Ferry Salmon 28.2.95). These containment measures include fine double screens on outflows from tanks containing the fish, screens on all drains in the building, with discharges passing through a secondary sump fitted with a screen and containing an electric fish killing device. Alarms are also installed to indicate flooding, any breakdown, power failure, or intruders (Otter Ferry 1995).

## 23.3 Environmental threat from transgenic salmon

23.3.1 The seriousness of the possible environmental consequences of an escape of transgenic salmon has been highlighted by a number of commentators (Kapuscinski & Hallerman 1990; DoE 1994b; NASCO 1996a). As with standard farmed salmon, the threat lies in both genetic effects on wild fish stocks and wider ecological effects, but both of these are massively heightened in the case of transgenic fish (NASCO 1996a).

23.3.2 The most obvious danger arises from the transmission of inserted, alien genes to wild fish if the transgenic fish escape and breed in the wild. Transgenic fish that have been reared to sexual maturity in trials have successfully passed the inserted gene to the next generation. However, transgenic organisms can be subject to mosaicism, which means they do not carry the gene in all their tissues, and this leads to wide variation in the offspring carrying the gene (Fletcher & Davies 1991). It has been noted that transmission of these genes to wild fish could lead to physiological and behaviour changes and that traits other than those targeted by the inserted gene(s) are likely to be affected (Kapuscinski & Hallerman 1990). Clearly, the outcome of such an event would be highly unpredictable.

23.3.3 In addition to the new genetic information they contain, transgenic fish also go through a process of extreme in-breeding during production (Devlin & Donaldson 1992). This means transgenic fish will be even less genetically diverse than normal farmed stock, magnifying the concerns raised about the threat of esaped salmon to the genetic integrity and local adaptations of wild populations (K. Hindar in MacKenzie 1996a).

23.3.4 The ecological impacts of escaped transgenic fish are equally unpredictable. Effects are likely to arise from enhanced competition both with wild salmon and other species. Transgenic salmon with faster growth rates may be more successful at attracting mates and thus inter-breed with or displace native populations faster than normal escaped fish (A. Kapuscinski in MacKenzie 1996a). Faster growing fish would also be expected to out-compete their wild counterparts for food, to eat more and to take larger prey earlier in the season, thus potentially impacting on other species. Furthermore, the introduction of traits such as antifreeze production into salmon could significantly extend the range of the species, and indeed salmon farming, northwards threatening the ecological integrity of whole new areas (Hindar 1993). The extent of the ecological impacts of transgenic fish will be related to the level of alteration of their performance, but it is predicted that such fish could destabilise and reorganise aquatic ecosystems (Kapuscinski & Hallerman 1990).

23.3.5 As a result of these concerns it has been widely proposed that any use of transgenic salmon should be contained, either physically, in secure self-contained units, and/or biologically, using sterile fish. However, physical containment is not considered viable in an industry dominated by cage-culture. Furthermore, current sterilisation methods are not considered 100% safe and sterile fish still present an ecological threat as they would compete for food and may attempt to breed, thus wasting the reproductive efforts of wild fish.

23.3.6 The importance of containment is not a view that is held universally, however. The promoting company A/F Protein Inc. has stated the fish should be managed like "standard salmon" (MacKenzie 1996a). Roger Doyle, a biologist working on the technology in Canada, supported this view by suggesting that if the foreign genes make the escaped salmon less fit they will die anyway, and if the genes make the resultant fish more fit he would be "glad we could help out" (MacKenzie 1996a).

## 23.4 Regulation of transgenic salmon

23.4.1 The development of the regulatory framework for genetically modified organisms in the UK has been usefully reviewed by Paddock (1995). Current UK legislation is largely determined by two European Union Directives introduced in 1990: 90/219/EEC Contained use of GMOs; and 90/220/EEC Deliberate release into the environment of GMOs. The former was implemented in the UK as The Genetically Modified Organisms (Contained Use) Regulations 1992, made under the Health and Safety at Work etc. Act 1974. The latter was implemented as the Environmental Protection Act 1990, Part VI and The Genetically Modified Organisms (Deliberate Release) Regulations, 1992 (made under EPA 1990). The rearing of transgenic fish at Otter Ferry Salmon is classified as "contained use" of genetically modified organisms (P.Logan pers. comm.).

23.4.2 The regulation of GMOs in the UK falls primarily to the Health and Safety Executive (HSE) and the Department of the Environment (DoE). Broadly, the HSE has responsibility for the human health aspects of GMOs and is the lead body with regard to the contained use of such organisms. For instance, HSE devised and enforces the containment and security precautions at Otter Ferry Salmon, with input from the Scottish Office and the DoE. Primary responsibility for the environmental aspects of GMOs and particularly their release into the environment falls to the DoE in England and Wales and to the Scottish Office in Scotland.

23.4.3 The EU Directive on Contained Use applies only to genetically modified micro-organisms (GMMs), which include bacteria, viruses and plant and animal cell cultures. However, the UK has gone further to include all GMOs in its Contained Use Regulations, under the Health and Safety Act. These regulations cover risk assessment, advance notification to the HSE of genetic modification activities, some of which require consent, safety and containment standards and disclosure of information (Paddock 1995). However, for non-micro-organisms, the regulations only cover human health and safety, not the environment.

23.4.4 Although the current transgenic salmon operation qualifies as contained use, any proposal to rear fish where there is considered to be a risk of escape, for instance in sea cages or a land-based facility that is not totally contained, would be classified as a deliberate release and would be subject to prior consent. The DoE has recently published guidance for experimental releases of genetically modified fish (DoE 1997b). This document deals mainly with the processes of risk assessment, management and monitoring of experimental releases but cites the release of fast-growing transgenic Atlantic salmon as a hypothetical example. The release of fertile transgenic salmon is described as presenting a high risk of damage to the environment occurring and various safeguards that would be necessary to reduce the risk to effectively zero are presented. Under current circumstances it is considered extremely unlikely that consent for such a release would be given (B. Parrish DoE pers. comm.).

23.4.5 The regulation of contained use of genetically modified organisms that are not GMMs, such as salmon, reveals some alarming short-comings. Key provisions of the Contained Use Regulations relate to the categorisation of the activity and the GMO to determine the necessary notification procedure and risk assessment. Categorisation by the type of operation, for instance whether for research or large scale commercial purposes, applies only to GMMs, not to other GMOs (such as salmon). The hazard categories also apply mainly to GMMs, and consider their effects on humans, animals and plants and the environment. The hazard categories applied to non-micro-organism GMOs (such as salmon) consider only their hazard to human health (Paddock 1995). These GMOs are classified as those which are as safe as the parental organism in conditions of containment, and those which are not. For example, whereas a cow producing human lactoferrin in its milk might fall into the "safe" category, a mouse modified to express prion protein genes for Creutzfeld-Jacob disease might not (ACGM 1996). The Otter Ferry transgenic salmon would meet this safety criterion (Otter Ferry 1995).

23.4.6 The Contained Use Regulations do not cover the environmental risks associated with the contained use of GMOs that are whole plants or animals. Although HSE has to be given advance notification of the intention to use premises for genetic modification purposes, there is no further requirement to notify HSE of operations involving GMOs that do not pose a human health risk (Paddock 1995). In the initial drafting of the Regulations it was proposed that they should cover both human health and environmental protection. However, this was opposed by the biotechnology industry and academic institutions and the regulations were redrafted, with the environmental protection requirements removed to the deliberate release regulations (P. Logan pers. comm.).

23.4.7 Another shortcoming of the Contained Use Regulations is the lack of provisions for monitoring, sampling or inspection of contained use operations, or for publicly accessible records.

23.4.8 Part VI of the Environmental Protection Act 1990 (EPA) is concerned with '... preventing or minimising any damage to the environment which may arise from the escape or release from human control of genetically modified organisms' (section 106(1)). While on first inspection the scope of the EPA appears to be all-embracing, much of it has not been brought into effect by specific regulations. For example, the Act requires an environmental risk assessment to be carried out before any GMO is imported, acquired, released or marketed (108(1)(a)) but does not specify that it must be suitable or sufficient. There is no requirement for the risk assessment to be provided to the HSE or any other authority. The Act merely requires that the person who carries out the risk assessment keeps it for a prescribed period, specified as 10 years by regulation in 1996 (SI 1106).

23.4.9 All proposals to deliberately release GMOs require prior consent (except in certain circumstances), which is co-ordinated by DoE under the guidance of the Advisory Committee on Releases to the Environment (ACRE) (Paddock 1995). However, the importation of GMOs is subject only to a risk assessment being conducted under the terms of the EPA. Furthermore, the scope of the EPA is limited to viable organisms or biological material which is capable of replication. The import of genetically modified DNA (not incorporated into organisms or cells), as used in the Otter Ferry operation, is not covered by the legislation.

23.4.10 In order to market GMOs or products containing GMOs within the EU, the Deliberate Release Regulations require the European Commission to be informed of the proposal and other EU member states to agree to it (Paddock 1995). The export of GMOs to markets outside the EU is beyond the powers of either domestic or EU legislation and would be regulated solely by the laws in the recipient country (B. Parrish pers. comm.). The UK Government expressly ruled out the control of transgenics for export under the EPA despite strong arguments that UK law should cover export, particularly to countries without adequate regulations (J. Kinderlerer, Sheffield Uni. pers. comm.).

23.4.11 The implications of these shortcomings in the case of transgenic salmon are serious:

i) There is no legal requirement to notify HSE or any other authority, of "contained" work with genetically modified fish. Any site that has already been notified to HSE for use for genetic modification purposes, for instance a company developing vaccines with GMMs, would not have to notify HSE of new operations involving transgenic fish (unless there are human health and safety implications). Thus HSE does not have a complete list of premises working with transgenic fish in the UK, nor does any other authority.

ii) Although a company or institution would have to notify the HSE of its initial genetic modification work at a site, there is no requirement for it to give notification of any change or further developments in its operations. Thus, a company that produced transgenic salmon from genetically manipulated ova would not need any consent, or to notify any authority, in order to breed a new generation of transgenic salmon from the fish produced. Under the Contained Use Regulations, a "significant change" in operations is only considered in terms of human health risk.

iii) Theoretically, only operations with full and guaranteed containment of transgenic fish should qualify as "contained use" rather than "deliberate release" of GMOs. However, given that the HSE does not legally have to be notified of operations involving transgenic fish, appropriate containment measures will not necessarily be devised or enforced. Furthermore, any operations that have not been reported to HSE are unlikely to detected as there are only three inspectors for all contained use of GMOs in the UK, including medical research work, which amounts to 600 establishments (P. Logan pers. comm.).

iv) There are no powers under UK law to prevent genetically manipulated DNA (that is not in an organism or other viable form) being imported into the UK for contained use. In addition, there are no powers to prevent transgenic organisms such as ova or adult salmon that are produced in the UK being exported to countries outside the EU, including those that have no effective laws to regulate the technology or provide safeguards against its potential environmental impacts.

## 23.5 The future of transgenic salmon

23.5.1 It has recently emerged that Otter Ferry Salmon has decided not to breed its transgenic fish and not to continue with the trial beyond June 1997, at which point it will have a full set of growth data (A. Barge pers.comm.). The reasons given for this decision are the environmental concerns about the technology and the regulations in place mean the company cannot see a way forward in the UK. Otter Ferry considers the trial to have been a success, having demonstrated that the technology is effective on a near-commercial basis, but considers there is not, at present, the public acceptance to pursue it commercially.

23.5.2 The reaction of the Scottish salmon farming industry has been to distance itself from the development of transgenic salmon. The SSGA's official policy on the matter is that it does not condone the use of transgenics in the production of salmon for human consumption. The industry states this position is driven partly by concern about consumer attitudes towards genetically modified food and partly by environmental considerations (W. Crowe pers.comm.). A survey of fish farmers in the UK in 1994 asked whether they thought the use of transgenic fish in fish farming was acceptable at present. Of the respondents, slightly more replied 'No' than 'Yes', but the largest group by a small margin did not know or did not feel informed enough to make a decision (DoE 1994b). The most important factor influencing fish farmers' opinions was given as consumer acceptance. Clearly, the salmon farming industry is acutely aware that its product is sold very largely on the natural image of wild salmon.

23.5.3 The current Scottish Office position is to oppose the genetic modification of salmon and it would strongly resist any move towards production in Scotland (D. Dickson pers. comm.). Also no Scottish Office research or development work is being conducted in this field (A. Munro pers.comm.). This position is perhaps not surprising, given the present antipathy of the salmon farming industry towards transgenics. However, Scottish Office scientists were initially supportive of the Otter Ferry project (A. Barge pers. comm.). Should public opinion become more accepting of biotechnology in food production, it seems likely the positions of both the salmon farmers and the Scottish Office would shift as well to embrace what has the potential to be a highly profitable development for the industry. Moreover, should other competitor producers of farmed salmon adopt transgenic technology, the Scottish industry may be forced to change in order to maintain its share of the international market.

23.5.4 The commercial production of genetically modified salmon in the UK appears unlikely, at least in the next few years. However, the Otter Ferry project has demonstrated it is possible and any other company could take over where this project left off. Otter Ferry is so confident about the growth rates achieved that it considers the technology would be economically viable in a commercial situation even with the expense of a totally contained system (A. Barge pers. comm.).

23.5.5 The release, or potential escape of genetically modified organisms as highly migratory as the salmon clearly represents an issue of international significance. Norway has a policy not to permit organisms modified by genetic engineering to be reared in the aquaculture industry (Mohr 1994). In deliberations in the North Atlantic Salmon Conservation Organisation (NASCO) both Norway and Iceland have proposed that transgenic salmonids should not be permitted in the commission area except in secure, self-contained facilities (NASCO 1996b). The International Council for the Exploration of the Seas (ICES) urges its member countries to establish strong legal measures to regulate any releases, including mandatory licensing of importation, use or release of GMOs. It also recommends that, whenever feasible, any releases of GMOs be reproductively sterile (ICES 1995). However, it should be born in mind that current methods of sterilisation are not considered 100% guaranteed if conducted on a commercial scale and, the risk of even one fertile transgenic fish escaping would be considered unacceptable (B. Parrish pers. comm.).

23.5.6 It is important to note that the Otter Ferry project was initiated with a view to exporting fast-growing salmon ova to Chile, which is the main importer of ova from Scotland (A. Munro pers. comm.). Chile is already at the forefront of low cost salmon production and is the second largest producer of farmed salmon in the world. Its production of 100,000 tonnes in 1995 is expected to reach 140,000 in 1996 (World Fish Report 7.11.96). It has been reported that Chile initially rejected a proposal to import transgenic Coho salmon on the grounds of feared consumer rejection and the threat to native fish (Financial Times 5.7.96). However, Otter Ferry considers its venture fell through because Chilean companies are looking to buy the transgenic technology directly from Canada, thus undermining the need for Scottish hatchery production. Furthermore, the Chilean salmon industry is thought to be confident that its major export market in Japan does not have the same consumer sensitivity to genetically engineered food as that seen in Europe (A. Barge pers. comm.).

23.5.7 Aqua Bounty Farms are selling the technology for fast-growing transgenic salmon not just in terms of higher profits for fish farmers and lowers costs for consumers, but also on the grounds that it will meet the needs of people in developing countries. This claim is seriously misleading as, although these fish grow faster, they are not better food converters and still require the same amount of food to grow as non-transgenic fish. The argument about "feeding the hungry" is popular within the biotechnology industry, providing a more publicly acceptable face for the technology.

23.5.8 The salmon farming industry is growing rapidly in parts of the world such as Chile, where environmental regulations are not as strict as those in Europe or North America but where companies are competing in the same market. It is conceivable that the transgenic salmon grown in Scotland could trigger ecologically disastrous developments on the other side of the world, which could, in turn, pressure the salmon farming industry elsewhere to follow suit. While scientific advance in this area is probably inevitable, the Government seems not to have foreseen the possible consequences. There is a need for a radical review of the legislation to deal with the issues that are now arising.

## 23.6 Recommendations

**23.6.1 Given the unacceptability of the release of genetically modified fish and the risk of any containment being breached, the commercial production of genetically modified fish has no future in the UK and should be prohibited.**

**23.6.2 The Regulations on Contained Use of GMOs must be revised to include full consideration of the environmental implications of non-micro-organism GMOs and to require notification to HSE of all contained use work on such GMOs.**

**23.6.3 Regulations should be introduced that require prior consent for the importation into the UK of genetically manipulated DNA (that is not in an organism or other viable form) for contained use.**

**23.6.4 Legislation should be introduced in the UK to regulate the export of GMOs to markets outside the EU.**

# 24 SEA LICE AND SEA TROUT

## 24.1 Sea trout decline

24.1.1 There has been a serious decline in sea trout (*Salmo trutta*) populations in western Scotland in recent years. There is little direct information on population levels in western Scotland but catch figures are available from rod and line fisheries, although these are not necessarily a good reflection of stock status due to the variability of fishing effort and flow conditions (WHSTSG 1995) and, indeed, accuracy of reporting (Walker et al 1992). Catch levels demonstrate a clear decline throughout western Scotland, particularly in the north-west region. Here, average reported catches over the last six years to 1994 fell to about 30% of the long-term mean since 1952 (Northcott & Walker 1996).

24.1.2 The decline in sea trout catches in the north-west has been apparent since the 1950s and dramatic variations in catches between years are common. However, in 1989 there was a further drop in the region to a new low (WHSTSG 1995). A drop in catches was also recorded at this time throughout western Scotland and in Wales and western England but, whereas catches outside Scotland have since recovered, the low in north-west Scotland persisted (Walker 1994). While the situation varies considerably between individual rivers, overall it has been described as so serious that there is real concern about the adequacy of the spawning populations to sustain the stocks (WHSTSG 1995). In addition, the decline has been characterised by a fall in mean weight, as a result of a falling proportion of older, large fish and reduced growth at sea. As egg production is a factor of the size of the fish, the reduction in weight of fish is presumed to have resulted in a dramatic reduction in the number of eggs being deposited (Walker 1994).

24.1.3 Similar patterns of decline have been recorded in western Ireland, where long-term trap census data are available. Here, monitoring of one river system revealed a decline in the survival of smolts that began in the mid-1980s, with a severe drop in 1989 from which stocks have not recovered. These data, and those from Scotland suggest the decline in sea trout stocks has arisen mainly from reduced survival at sea (Northcott & Walker 1996).

24.1.4 Although features of the decline vary to some extent between the countries, the similarity of the problem strongly indicates common causal factors. In Ireland, the sea trout problem has been the subject of extensive examination through the establishment by the government of the scientific Sea Trout Working Group (STWG) and the Sea Trout Task Force (STTF), which was succeeded in 1994 by the Sea Trout Monitoring and Advisory Group (STMAG). In Scotland, the West Highland Sea Trout and Salmon Group (WHSTSG) was established in 1994 and addressed the sea trout decline (see 22.5.2 and 24.5.1). A further group, the Scottish Salmon Strategy Task Force, was set up in 1995 (see section 25).

24.1.5 The sea trout decline has been documented by a number of commentators (Walker 1994; Northcott & Walker 1996; Kelton 1996). The factors that have been considered as potential contributors to the decline are numerous and range from predation and food availability to disease, climate and sea lice. The evidence considered on the many possible causes of the phenomenon has been reviewed extensively in the Irish Sea Trout Working Group reports (STWG 1994;1995) and in the proceedings of the Atlantic Salmon Trust conference "Problems with Sea Trout and Salmon in the Western Highlands" (Anon 1994).

## 24.2 Significance of sea lice

24.2.1 Generally, one common and important factor that has been identified in the sea trout decline is the prevalence of sea lice *Lepeophtheirus salmonis* infesting smolts soon after they move to sea in spring. This problem was first identified in 1989 in western Ireland, where sea trout were found to be entering rivers prematurely, in poor condition and with heavy burdens of largely juvenile sea lice, causing severe damage and even death of fish (Whelan 1993). The lice are thought to cause the premature return and there is growing evidence to support this from Norway where extraordinarily heavy infestations have been recorded on sea trout post smolts (Birkeland & Jakobsen 1995). In Scotland also, very high numbers of sea lice have been found infesting sea trout in 1991 and 1992 (McVicar et al 1994) and specifically on the post-smolt trout studied in 1994 (Table 1 in Northcott & Walker 1996).

24.2.2 There seems to be less agreement over the interpretation of the sea lice data and the significance of these parasites to the decline of sea trout, relative to other causal or potentially predisposing factors. Of the many potential contributory factors that had been considered by the Sea Trout Working Group in Ireland, only diseases, migratory stress and sea lice were still under active consideration by 1992, and by 1993 disease and migratory stress had been discounted. This left sea lice as the main focus of STWG deliberations in 1994 (STWG 1994). Climatic variations were clearly recognised in Ireland as an important factor affecting smolt numbers and survival, which can be adversely affected by high temperatures and low rainfall. However, it has been observed that the geographic definition of the poor trout survival in 1989 and 1990 (largely confined to the mid-west region) could not be attributed to weather conditions that were similar along the whole coast (Kelton 1996).

24.2.3 The Scottish Office has focused particularly on two factors: unusual climatic conditions, notably in 1989/90, and the impact of heavy sea lice infestations (SOAEFD 1995). Research at the Marine Laboratory has looked at climatic changes that may have influenced marine survival of west coast salmon and sea trout. After leaving their native rivers, sea trout are believed to restrict their movements to sea lochs and close coastal waters, so changes in these areas are assumed to be of most relevance (Turrell 1994). Turrell's analysis shows that in the period from 1989 to 1991 particularly extreme conditions occurred that may have been of importance to the sea trout decline. High salinity and temperature in Scottish coastal waters may have affected local plankton communities. In addition, the weather patterns at this time caused a delay in the spring phytoplankton bloom which may have resulted in food species not being available when the smolts entered the sea. The smolts themselves may also have been affected by the mild winters, impairing their adaptation to sea conditions or the timing of their descent.

24.2.4 It has further been postulated that climatic conditions may have influenced the effects of sea lice on sea trout. For instance, a sea lice epizootic was reported in Canada in 1939 and 1942 causing severe damage to salmon. This event was associated with conditions of drought and high temperatures. It is suggested that the unusually warm conditions recorded between 1988 and 1992 in northern Europe may have reduced the generation time of the sea lice, increased their feeding activity and their survival over winter (reviewed by Northcott & Walker 1996).

24.2.5 Scottish Office research on the infestation of sea lice on sea trout has found higher levels of infestation to occur in north-western stocks compared to those in other parts of Scotland (McVicar et al 1994). Sampling of both wild and experimentally caged sea trout produced no evidence of other disease that could be implicated in the decline (Northcott & Walker 1996).

## 24.3 Significance of salmon farms as a source

24.3.1 Most Scottish Office scientists seem to agree that, on the basis of information currently available, an increase in sea lice is a likely source of much of the increased marine mortality of sea trout that has occurred in recent years. However, there is less agreement on the extent to which the salmon farming industry is a significant source of the sea lice that are infesting sea trout.

24.3.2 Evidence from Scotland, Ireland and Norway on the spatial, and to a lesser extent the temporal distribution of sea lice infestations on sea trout has been found to be consistent with salmon farms being a major source of the parasites. In Ireland, a highly significant relationship was found between linear distance from the nearest salmon farm to the sea trout river mouth and the level of juvenile lice on sea trout. This correlation was limited to a 20 km radius from the farm (STWG 1995). Moreover, the significance of the distance relationship weakened progressively over the years 1992 to 1994 as the level of lice infestations on fish farms decreased. Similarly, Norwegian research found that a higher number of prematurely returned and lice infested sea trout post smolts were observed in rivers close to salmon farms (ranging from 47% to 94% of fish) than in more distant rivers (0% to 50% of fish) (Birkeland 1996). The high number of sea lice larvae present in coastal waters and infesting post-smolts as they leave the rivers in spring is considered less likely to originate from wild salmonids than from farmed Atlantic salmon (Birkeland et al 1995).

24.3.3 Scottish Office scientists acknowledge that the pattern of sea lice infestation of sea trout in Scotland coincides with the main distribution of salmon farms, most of which are infested with lice and are known to release infective stages. Cage experiments also produced a correlation between the accumulation of sea lice on sea trout and distance from the nearest salmon farm cages (McVicar 1994). These associations are similar to those found in western Ireland which has led to a linking of sea lice from salmon farms with the sea trout decline. However, McVicar (1994) reports that it is difficult to determine whether farmed lice contribute to the infestation of wild sea trout in Scotland for various reasons including that background levels of the parasite and "normal" infestation levels of sea trout are unknown. He also observes the lesser severity of sea lice damage on Scottish sea trout compared to that in Ireland does not correlate with the much larger size of the Scottish salmon farming industry.

24.3.4 Extensive sampling of sea lice infestations on sea trout was undertaken by the Fresh Water Fisheries Laboratory and the Marine Laboratory, Aberdeen in 1994, including analysis of the relationship between sea lice levels and distance from salmon farms. Although the interim findings of this work were made available to the WHSTSG and have been cited in Kelton (1996), the final report is not due to be published until mid-1997 (S. Northcott, Freshwater Fisheries Lab. pers. comm.).

24.3.5 In Ireland, the Sea Trout Working Group in its report to the Minister of the Marine in 1995 interpreted the research findings in a decisive and precautionary way, concluding that "while the evidence available to date has not disclosed a causative relationship between lice on farmed salmon and the collapse of the sea trout, the Working Group has now been able to demonstrate, for the first time, that a highly significant relationship exists" (STWG 1995). In contrast, the West Highland Sea Trout and Salmon Group in Scotland reached a more conservative conclusion that "while there was circumstantial evidence that sea lice had been implicated, and a widespread perception that this was the case, there was a lack of conclusive proof that heavy infestation by sea lice of wild stocks arising from salmon farming had been the principal cause of the decline of sea trout and some salmon stocks in the West Highlands" (WHSTSG 1995).

24.3.6 It should be clear that the type of monitoring work conducted to date cannot, by its nature, establish conclusively a causal relationship between the status of sea trout and salmon farm sea lice when there are so many variable factors. However, one line of investigation that it is argued will shed more conclusive light on the significance of salmon farms as a source for the sea lice is being conducted at the University of St Andrews in collaboration with the Scottish Office Freshwater Fisheries Laboratory (University of St Andrews 1996). The genetic differentiation in sea lice populations is being studied using a DNA marker technique that should determine the proportion of sea lice infesting wild sea trout which have emanated from salmon farms. Preliminary results show there are clear distinctions between sea lice on farmed fish and on wild fish. However, some of the lice from wild sea trout do carry DNA markers that are consistent with sea lice from salmon farms. The report of this preliminary study is not yet available and the results from the full sampling programme undertaken in 1996 are unlikely to be available for a further year. The proposed duration of the DNA project is three years, but full funding for this research has yet to be secured (S. Northcott pers. comm.).

24.3.7 In November 1996 an international workshop was held in Edinburgh on the interaction between salmon lice and salmonids. The meeting was held under the auspices of ICES (the International Council for the Exploration of the Sea) and its remit was to review the available information on the issue and to identify deficiences in the data and further research that is needed. A full report of this workshop is expected to be published as an official ICES document late in 1997 (A. McVicar, Scottish Office Marine Lab. pers. comm.). A further ICES/NASCO symposium was held in Bath in April 1997 on the interactions between salmon culture and wild stocks of Atlantic salmon. This meeting addressed both the scientific aspects and the management implications of not only sea lice and sea trout, but also other disease and genetic interactions between farmed salmon and wild stocks.

## 24.4 Remedial action in Ireland

24.4.1 Given that it has not been possible to establish conclusive proof of the cause of the sea trout decline, probably the area of greatest divergence of opinion over this issue is the nature and level of action judged to be appropriate in order to counteract the problem.

24.4.2 In Ireland, the problem appears to have been clearly defined at an early stage, resulting in action being taken quickly to initiate studies. The role of the salmon farms as a source of sea lice was actively investigated, including the introduction of official monitoring of sea lice on salmon farms in 1991.

24.4.3 The Sea Trout Task Force Report in 1994 recommended that "the virtual elimination of lice on and in the vicinity of sea farms must be a constant priority of management and regulatory practice" (STTF 1994). Specifically, it recommended the treatment of lice and harvesting of salmon in late winter to prevent the spring build-up. It called for longer term corrective measures to include site fallowing, single bay management, reduced stocking densities, relocation to other licensed sites and vaccination (when developed). It proposed the establishment of a control area free of salmon farming for research purposes and that all information derived from farm inspections be made available to a continuous monitoring agency. Further, the STWG recommended a prohibition on the siting of new salmon farms or increased salmon production within 20 km of a sea trout river mouth (STWG 1995).

24.4.4 The Sea Trout Monitoring and Advisory Group (STMAG) was charged with taking forward STTF's recommendations. The group has additionally identified the need for farm site licensing provisions specifically for fallowing purposes, limited to one year and expressly prohibiting use for new or increased production. It has also called for new legislation providing for a comprehensive and transparent licensing system, including penalties for non-compliance with any requirements. It recommends that sea lice on farms be maintained at the lowest possible levels, with inspections to be conducted 14 times per year (STMAG 1995). In 1996 further measures were proposed regarding single bay management and site fallowing arrangements in order to reinforce what was reported as the "substantial progress already made in the mangement of sea lice on salmon farms" (STMAG 1996). Additional sea trout monitoring provisions were also proposed. These recommendations have been accepted by the Minister and are in the process of being implemented (E. Colleran STMAG pers.comm.).

24.4.5 Although a wide range of action is being taken to address the sea trout problem in Ireland, the situation there is not ideal. The profusion of expert groups and the number of participants with conflicting interests are seen as compromising the objectivity of the science and the policy advice being produced. Clearly this is not the best climate for policy development and it would be regrettable if this situation were allowed to develop in Scotland.

## 24.5 Remedial action in Scotland

24.5.1 In Scotland, the key response to the sea trout decline has been the establishment of the West Highland Sea Trout and Salmon Group (WHSTSG) in 1994 (see 22.5.2), consisting of representatives of salmon fisheries and anglers, the SSGA, Crown Estate and Scottish Office. This Group worked over the course of a year to establish the nature of the problem and the possible underlying causes, paying special attention to the infestation by sea lice and the possible role of salmon farms as the source (WHSTSG 1995). Broadly, the group recognised the need for further research but proposed an immediate Plan of Action to protect and regenerate the endangered stocks. This includes proposals to minimise any adverse impact of sea lice, and a number of wild fishery research and management measures, including restriction on angling effort.

24.5.2 The main recommendation of the Action Plan was the establishment of local Fishery Trusts, with representation from District Salmon Fishery Boards, fish farming interests, conservation bodies and other relevant agencies, in order to develop and implement the plan on a local level. This proposal has been widely supported and five Fishery Trusts have been now been established, covering the area from Sutherland to Lochaber and the Western Isles. Each trust employs a biologist and sets its own objectives, based on the research and management needs of the area. As the trustees include fish farmers, local development proposals can be jointly considered by the whole trust in the light of their implications for wild stocks. The trusts are also open to public participation and are, therefore, considered to provide an open forum for airing concerns about the fish farming industry (A.Wallace pers. comm.).

24.5.3 Given WHSTSG's conclusion that "there was a lack of conclusive proof" that sea lice from salmon farming had been the principal cause of the decline of sea trout, its recommendations with regard to salmon farming are more modest than those made in Ireland. The objectives set are to maximise the health and welfare of farmed salmon and to minimise interaction with wild sea trout and salmon. However, the actual recommendations go little further than to require the industry to continue existing policies with regard to stocking, disease and parasite treatment, research programmes, stock protection and containment, and site fallowing and rotation. In addition, the presumption against siting new salmon cages at the mouth of sea trout and salmon rivers is to be maintained. This part of the plan has caused considerable objection, provoking the Salmon and Trout Association, which participated in the group, to state the report "ducks the central issue, sea lice" (SAT 1995).

24.5.4 The Scottish Office is continuing research into sea trout and sea lice. Work at the Fresh Water Fisheries Laboratory includes the DNA project and an experimental sea trout field project on River Shieldaig, with a permanent trapping site. However, full funding for both these projects has not yet been achieved (S. Northcott pers. comm.). Work at the Marine Laboratory is focused mainly on the environmental effects of new chemical treatments for sea lice and the ongoing development on a sea lice vaccine (A. Munro pers. comm.). Although the Marine Laboratory has a Fish Diseases Unit with six inspectors, no monitoring for sea lice on salmon farms is conducted as it is not a notifiable condition. Salmon farms undertake their own monitoring of sea lice for treatment purposes. However, the uneven distribution of sea lice between hosts means that a far more comprehensive sampling effort would be required to determine sea lice population and production levels and would involve considerable expense (S. Northcott pers. comm.).

24.5.5 An internal review of sea trout and farm sea lice research by the Marine and Freshwater Fisheries Laboratories has recently been conducted, setting out options for further work. The outcome of this review, in terms of the direction and scale of future work, has not yet been determined (A. Munro pers. comm.). Current Scottish Office policy is to undertake research that will pin down the source of the problem (D. Dickson pers. comm.). However, very substantial research effort would be required to meet this objective and it is not clear if the Scottish Office, which controls the research budget, will dedicate sufficient funds to this area.

24.5.6 In the meantime, the policy of the Scottish Office is to encourage practical measures to be taken on the ground through the Fishery Trusts (D. Dickson pers. comm.). This does not include the type of precautionary action being taken by the Irish government to regulate the impact of the salmon farming industry in order to minimise any potential adverse effects it may be having. Indeed, further commitments by the Scottish Office appear to have been on hold pending the outcome of Lord Nickson's Salmon Strategy Task Force (see section 25).

24.5.7 Although many aspects of the sea trout decline are common to both Scotland and Ireland, there have been very different responses in the two countries. This difference appears to arise, at least in part, from the relative importance of fish farming and sea trout angling. The authorities are trying to tread a delicate line between the apparently conflicting interests of two commercial lobbies, both facing a common problem. It appears that the response of the Irish government reflects the interests of the more prominent angling sector, whereas that of the Scottish Office could be regarded as more sympathetic to those of the salmon farming industry. Indeed, the WHSTSG report refers to the "natural, economic and other constraints" on its Action Plan (WHSTSG 1995). Presumably these include political constraints, coloured by the undoubtedly influential Scottish salmon farming industry. What seems to have been under-represented in the consideration of the problem is the need to protect the sea trout in its own right as part of the natural heritage of Scotland.

## 24.6 Recommendations

**24.6.1 The Scottish Office should clarify and make public its current and proposed research commitments on sea trout, sea lice and salmon farms as a possible source of infestation. Existing research findings should be published at the earliest opportunity.**

**24.6.2 A programme of precautionary measures designed to minimise any potential impacts of salmon farm derived sea lice on sea trout should be drawn up by SEPA; to include good farm siting and husbandry by the industry and the monitoring of farm sea lice levels, treatments and other remedial measures by SEPA.**

**24.6.3 SEPA, in conjunction with SOAEFD, should investigate and provide direction to the industry on non-chemical methods of sea lice control through husbandry and site management measures; to include stocking densities, site fallowing, site selection and single-bay management agreements (see 18.3). The implementation and efficacy of these measures should be independently assessed.**

**24.6.4 This regulatory function should be carried out by the unified monitoring body established under SEPA, in line with SEPA's responsibility for environmental protection and the safeguard of aquatic flora and fauna.**

## 25 SCOTTISH SALMON STRATEGY TASK FORCE

25.1 The Scottish Salmon Strategy Task Force (SSSTF) was established by the Secretary of State for Scotland in November 1995 under the chairmanship of Lord Nickson. Its terms of reference were "to consider the challenges and opportunities facing Scottish salmon fisheries with a view to recommending a strategy for the management, conservation and sustainable exploitation of the stocks into the next century". The task force agreed that the aim of the strategy was "to improve and maintain wild salmon fisheries for the economic and social benefit of Scotland, by increasing salmon abundance and conserving the diversity of salmon populations".

25.2 The Report of the SSSTF was published in February 1997 (SSSTF 1997), detailing a strategy that addresses salmon fisheries administration and management and also salmon resource conservation. Within this latter section, the report makes a number of recommendations on the management and regulation of the salmon farming industry. In particular, the task force recommends that:

- fish farmers should reduce the levels of sea lice infestations at farms, achieving this through the adoption of husbandry techniques which reduce levels of disease and parasitism, and through access to environmentally acceptable medicines and vaccines;

- steps be taken to reduce the incidence of escapes from freshwater and marine fish farms through implementation of the NASCO recommendations on measures to minimise the impacts from salmon aquaculture on wild salmon stocks and introduction of appropriate powers to ensure the recapture of escaped fish (NASCO 1994b);

- any commercial producton of transgenic salmon is confined to shore-based farms, from which there is no possibility of escape or entry to the wild; and

- there should be a presumption against the siting of fish farm cages on freshwater lochs.

25.3 The task force also highlights the need for clear planning policy guidance for fish farms. It recommends that an independent regulatory authority should be established with powers to control the siting of fish farms, inspect fish farms and enforce the adoption of measures to reduce the impact of fish farming upon wild populations and on the environment. It recommends this authority be vested with powers to introduce a system of zoning for marine fish farms, allowing for moratoria on expansion of production or further development in specified areas.

# CONCLUSION

Any industry that establishes itself within the beauty, richness and sensitivity of the Scottish sea loch and coastal environment, and the economically fragile coastal communities that depend upon it, must respect the ecological constraints of that environment. This respect will earn the industry a secure future by protecting the marine resource which it needs for survival.

The salmon farming industry is no exception. It has grown very rapidly in Scotland and has undoubtedly become an important contributor to local employment and economies. However, it has been allowed to do so with minimal strategic guidance and regulation and in a climate of strong international competition. This has resulted in increasingly intensive practices and signs are that it may now be operating beyond the ecological constraints of its surroundings. Given the still limited understanding of the marine and coastal environment, far less the impact of the salmon farming industry, it cannot be considered to be operating within the parameters of the precautionary principle.

The continued reliance on environmentally harmful therapeutants and chemicals, the use of highly intrusive devices to deter wildlife from farm sites and the effects on wild fish stocks through escapes of farmed salmon and through disease transmission, all attest to an industry that is not working in harmony with its surroundings but may in fact be inflicting considerable and potentially irreversible harm. In this paper, SWCL highlights some of these areas of concern and makes recommendations for changes both in the way salmon farms operate and in the framework in which they operate.

There is now an opportunity for fundamental and long overdue reform of the overall structure and functioning of the planning and regulation of salmon farming industry. SWCL is taking this opportunity to put forward an option for change.

We propose the Scottish Office should produce clear strategic guidance for the development of the industry as a matter of urgency. We propose that local planning authorities should be given responsibility for planning decisions on the siting of marine fish farms. We further propose that SEPA be charged with responsibility for environmental assessment and the role of regulating the operations of the industry, insofar as they are relevant to its environmental impact. Critically, these changes should be coupled with an increased responsibility taken on by the industry itself to give due care to the environment.

We recognise this package of proposals is just one of several possible options, but one we consider can provide for proper environmental protection and development of the industry on a more accountable, consistent and sustainable basis. The purpose of this report is to promote further debate of the issues raised and to hasten the introduction of appropriate regulatory and operational changes. The report is for consideration in discussions we trust will ensue in the near future as the Scottish Office, industry and regulatory and other interested bodies together seek the best arrangements to ensure the environment is protected.

## Acronyms and abbreviations used

| | |
|---|---|
| ACGM | Advisory Committee on Genetic Modification |
| ACRE | Advisory Committee on Releases to the Environment |
| ADD | Acoustic Deterrent Device |
| ADRIS | Association of Directors and River Inspectors for Scotland |
| ATC | Animal Test Certificate |
| BKD | Bacterial Kidney Disease |
| CEC | Crown Estate Commission |
| COPA | Control of Pollution Act 1974 |
| CRPB | Clyde River Purification Board |
| DML | Dunstaffnage Marine Laboratory |
| DoE | Department of the Environment |
| DTI | Department of Trade and Industry |
| EA | Environmental Assessment |
| EPA | Environment Protection Act 1990 |
| EQS | Environmental Quality Standard |
| EU | European Union |
| FEPA | Food and Environment Protection Act 1985 |
| FFAG | Fish Farming Advisory Group (of SEPA) |
| GMM | Genetically Modified Micro-organism |
| GMO | Genetically Modified Organism |
| GSP | Golden Sea Produce |
| HRPB | Highland River Purification Board |
| HSE | Health and Safety Executive |
| ICES | International Council for the Exploration of the Sea |
| IPN | Infectious Pancreatic Necrosis |
| MA | Marketing Authorisation |
| MAFF | Ministry of Agriculture, Fisheries and Food |
| MRL | Maximum Residue Limit |
| MSD | Merck Sharp and Dohme |
| NASCO | North Atlantic Salmon Conservation Organisation |
| PSP | Paralytic Shellfish Poisoning |
| RPB | River Purification Board |
| RSPB | Royal Society for the Protection of Birds |
| SAC | Special Area of Conservation |
| SEPA | Scottish Environment Protection Agency |
| SFIA | Sea Fish Industry Authority |
| SFT | Statens forurensningstilsyn (Norwegian Pollution Control Authority) |
| SIC | Shetland Islands Council |
| SNH | Scottish Natural Heritage |
| SOAEFD | Scottish Office Agriculture, Environment and Fisheries Department (previously SOAFD – Scottish Office Agriculture and Fisheries Department until 1995 and DAFS – Department of Agriculture and Fisheries for Scotland until 1990) |
| SPA | Special Protection Area |
| SSGA | Scottish Salmon Growers Association |
| SSQC | Shetland Seafood Quality Control |
| SSSI | Site of Special Scientific Interest |
| SSSTF | Scottish Salmon Strategy Task Force |
| STWG | Sea Trout Working Group (Ireland) |
| STTF | Sea Trout Task Force (Ireland) |
| STMAG | Sea Trout Monitoring and Advisory Group (Ireland) |
| SWCL | Scottish Wildlife and Countryside Link |
| TBT | Tri-butyl Tin |
| UFAW | Universities Federation for Animal Welfare |
| VMD | Veterinary Medicines Directorate |
| VPC | Veterinary Products Committee |
| WHSTSG | West Highland Sea Trout and Salmon Group |

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